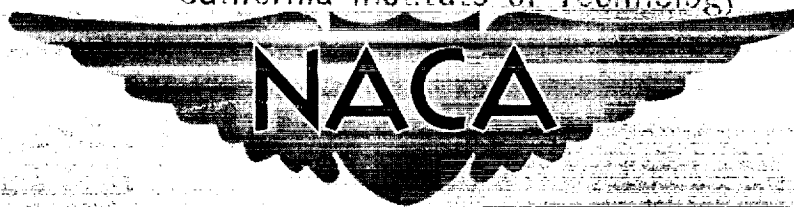


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# RESEARCH MEMORANDUM

ALTITUDE-WIND-TUNNEL INVESTIGATION OF  
J47 TURBOJET-ENGINE PERFORMANCE

By E. William Conrad and Adam E. Sobolewski

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Cleveland, Ohio

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RESEARCH MEMORANDUM

## ALTITUDE-WIND-TUNNEL INVESTIGATION OF

## J47 TURBOJET-ENGINE PERFORMANCE

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## SUMMARY

An investigation has been conducted in the NACA Lewis altitude wind tunnel to evaluate the performance of the J47 turbojet engine over a range of simulated altitudes from 5000 to 50,000 feet, simulated flight Mach numbers from 0.21 to 0.97, and a complete range of engine speeds. Data are presented to show the effects of altitude at a flight Mach number of 0.21 and of flight Mach number at an altitude of 25,000 feet. The performance data are generalized by two methods to determine the range of flight conditions for which engine performance may be predicted from performance data obtained at a given flight condition.

Engine-performance parameters obtained at a given altitude and flight Mach number could be used to predict engine performance for only a limited range of altitudes and corrected engine speeds. From the engine pumping characteristics presented, jet thrust could be predicted for any desired flight Mach number and exhaust-gas temperature for engine-pressure ratios above approximately 1.4 at altitudes from 5000 to 50,000 feet. The decrease in temperature-limited engine speed with increasing altitude indicated the need for a variable-area exhaust nozzle.

The specific fuel consumption at temperature-limited engine speed and a flight Mach number of 0.21 varied from 1.20 to 1.30 pounds per hour per pound of net thrust over the range of altitudes investigated. A minimum specific fuel consumption of 1.05 pounds per hour per pound of net thrust was obtained at an engine speed of approximately 6400 rpm at altitudes from 15,000 to 45,000 feet. Changes in flight Mach number at rated engine speed had no appreciable effect on specific fuel consumption. At lower engine speeds, however, the specific fuel consumption increased as the flight Mach number was raised.

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At an altitude of 25,000 feet, the internal drag of a windmilling engine varied from 2 percent of the available net thrust at a true airspeed of 200 miles per hour to 15 percent at a true airspeed of 650 miles per hour.

## INTRODUCTION

An investigation has been conducted in the NACA Lewis altitude wind tunnel to determine the over-all performance, component performance, and operational characteristics of a J47 turbojet engine over a wide range of simulated flight conditions.

Data are presented in graphical form to show the engine performance over a range of altitudes from 5000 to 50,000 feet and flight Mach numbers from 0.21 to 0.97. The effect of altitude is shown at a flight Mach number of 0.21 and the effect of flight Mach number is shown at an altitude of 25,000 feet. Performance data are generalized by two methods to determine the range of flight conditions for which engine performance may be predicted from performance data obtained at a given flight condition. Curves are presented to show the windmilling characteristics of the engine. All engine performance data obtained in the investigation are also presented in tabular form.

## DESCRIPTION OF ENGINE

The J47 turbojet engine used in the altitude-wind-tunnel investigation (fig. 1) has a sea-level static thrust rating of 5000 pounds at an engine speed of 7900 rpm and a turbine-outlet gas temperature of 1275° F. At this rating the air flow is approximately 94 pounds per second. The engine has a 12-stage axial-flow compressor with a pressure ratio of approximately 5.1 at rated engine speed, eight cylindrical direct-flow-type combustion chambers, a single-stage impulse turbine, and a fixed-area exhaust nozzle. The exhaust nozzle, which was used in this investigation and was designated standard, had an outlet area of 280 square inches. This exhaust nozzle produced a turbine-outlet temperature of approximately 1275° F at a flight Mach number of 0.21, an altitude of 5000 feet, and an engine speed of 7900 rpm. The over-all length of the engine excluding the exhaust nozzle is 143 inches, the maximum diameter is approximately 37 inches, and the total weight is 2475 pounds.

Air enters the engine through an annular inlet (fig. 2) and passes into the compressor through a row of inlet guide vanes. The air is discharged from the compressor through two rows of straightening vanes. From the annular outlet of the compressor, the air flows into the combustion chambers where it is mixed with fuel injected through duplex fuel nozzles. The mixture is burned and the hot gases of combustion flow through the turbine-inlet stator blades, the turbine, and into the atmosphere through the tail pipe and the exhaust nozzle.

### INSTALLATION

The engine was mounted on a wing in the test section of the altitude wind tunnel (fig. 1). Dry refrigerated air was supplied to the engine from the tunnel make-up air system through a duct connected to the engine inlet. A frictionless slip joint in the duct made possible the measurement of engine thrust and drag by the tunnel balance scales. The air flow through the duct was throttled from approximately sea-level pressure to a total pressure at the engine inlet corresponding to the desired flight Mach number at a given altitude.

Instrumentation for measuring pressures and temperatures was installed at various stations in the engine (fig. 2). Instrumentation for measuring air flow was installed at the inlet-air-duct venturi throat (station r), the engine inlet (station 1), and the exhaust-nozzle outlet (station 7).

### PROCEDURE

Thrust values were calculated from tunnel balance-scale measurements and also from values of gas flow and jet velocity obtained from measurements with the exhaust-nozzle survey rake. The exhaust-nozzle jet-velocity coefficient, defined as the ratio of scale jet thrust to rake jet thrust, is shown as a function of exhaust-nozzle pressure ratio in figure 3. Engine performance is based on thrust values obtained from the balance scales because this method includes the losses resulting from the inefficiency of the exhaust nozzle.

Symbols and methods of calculation are given in the appendix.

Performance data were obtained at the following altitudes and flight Mach numbers:

| Altitude<br>(ft) | Flight Mach number           |
|------------------|------------------------------|
| 5,000            | 0.21                         |
| 15,000           | 0.21, 0.53                   |
| 25,000           | 0.21, 0.53, 0.72, 0.85, 0.97 |
| 35,000           | 0.21, 0.53, 0.72             |
| 45,000           | 0.21, 0.53                   |
| 50,000           | 0.21                         |

Complete ram-pressure recovery at the compressor inlet was assumed in the calculation of flight Mach number. The fuel used was AN-F-32 with a lower heating value of 18,550 Btu per pound. The engine-inlet air temperature was held at approximately NACA standard values for each simulated flight condition except those of high altitude and low Mach number. Engine-inlet air temperatures below 439° R were unobtainable.

## RESULTS AND DISCUSSION

All the data obtained in the performance investigation of the engine with a standard exhaust nozzle are compiled in table 1. The engine-inlet pressures and temperatures deviated slightly from the desired inlet conditions. The data presented graphically in non-generalized form have therefore been adjusted to NACA standard altitude conditions by means of the factors  $\delta_a$  and  $\theta_a$  (appendix A).

### Engine Performance

Effect of altitude. - Engine-performance data obtained at a flight Mach number of 0.21 at altitudes from 5000 to 50,000 feet are presented to show the effects of altitude on net thrust, air flow, fuel flow, specific fuel consumption, fuel-air ratio, and exhaust-gas total temperature in figure 4. Engine net thrust, air flow, and fuel consumption decreased consistently as the altitude increased (figs. 4(a) to 4(c)). Data obtained at high engine speeds are not shown for an altitude of 15,000 feet because the flight Mach number was inconsistent with other altitudes. At altitudes above 15,000 feet, the maximum engine speed was limited by turbine-outlet temperature.

The specific fuel consumption (fig. 4(d)) was essentially constant for altitudes from 5000 to 45,000 feet at engine speeds above 7200 rpm and for altitudes from 15,000 to 45,000 feet at

engine speeds above 5750 rpm. In the engine-speed range between 4500 to 6600 rpm, the highest specific fuel consumption occurred at an altitude of 5000 feet; at engine speeds above 6600 rpm, the highest specific fuel consumption occurred at an altitude of 50,000 feet. The data indicated no consistent altitude effect at engine speeds below 5750 rpm, probably because of large variations in component efficiencies in the low engine-speed range. The minimum specific fuel consumption of 1.05 pounds per hour per pound of net thrust was obtained at an engine speed of approximately 6400 rpm at altitudes from 15,000 to 45,000 feet. The specific fuel consumption at temperature-limited engine speed varied from 1.20 to 1.30 over the range of altitudes investigated.

The engine fuel-air ratio (fig. 4(e)) increased with altitude at engine speeds above 4500 rpm. Data obtained at lower engine speeds indicated no consistent altitude effect.

The exhaust-gas temperature (fig. 4(f)) decreased with an increase in altitude at low engine speeds and increased with altitude at high engine speeds. A change in altitude from 5000 to 25,000 feet resulted in a decrease in temperature-limited engine speed from 7880 to 7550 rpm. The trend of the data indicates that an increase in altitude beyond 25,000 feet would further reduce the maximum permissible engine speed. Inasmuch as maximum thrust is obtained at full engine speed (7900 rpm), and maximum exhaust-gas total temperature, the desirability of using a variable-area exhaust nozzle to permit operation at full engine speed at all altitudes is evident.

Effect of flight Mach number. - Performance data obtained at an altitude of 25,000 feet and flight Mach numbers of 0.21 to 0.97 are presented in figure 5 to show the effect of flight Mach number on net thrust, air flow, fuel flow, specific fuel consumption, fuel-air ratio, and exhaust-gas total temperature.

As the flight Mach number was raised, the net thrust decreased at engine speeds below 6800 rpm and increased at higher engine speeds for flight Mach numbers above 0.53 (fig. 5 (a)). An increase in Mach number from 0.21 to 0.53 at engine speeds above 7000 rpm had no appreciable effect on the net thrust. The engine air flow (fig. 5(b)) increased consistently with an increase in flight Mach number. As the flight Mach number was increased, the engine fuel consumption (fig. 5(c)) decreased at engine speeds below 6150 rpm and increased at higher engine speeds. At temperature-limited engine speed, the specific fuel consumption based on net thrust (fig. 5(d)) increased from 1.21 to 1.43 as

the flight Mach number increased from 0.21 to 0.97. This variation of specific fuel consumption based on net thrust with flight Mach number increased at the low engine speeds. The minimum specific fuel consumption of 1.05 pounds per hour per pound of net thrust occurred at a flight Mach number of 0.21 and an engine speed of approximately 6400 rpm.

The engine fuel-air ratio (fig. 5(e)) decreased at all engine speeds as the flight Mach number was raised. The exhaust-gas total temperature (fig. 5(f)) was, in general, reduced by an increase in flight Mach number at all engine speeds except between 7000 and 7500 rpm, where a change in flight Mach number had no appreciable effect. Maximum engine speed was limited by exhaust-gas total temperature at flight Mach numbers below 0.72.

Generalized performance. - Altitude performance data for a flight Mach number of 0.21 have been generalized to standard sea-level conditions by use of the correction factors  $\delta$  and  $\theta$  (reference 1). In the development of this method of generalization, it was shown that these correction factors alone were insufficient to reduce the results completely to a single curve. The use of additional parameters, such as flight Mach number and Reynolds number, may be necessary for a complete generalized description of engine characteristics. Changes in flight Mach number or changes in component efficiency associated with changes in Reynolds number therefore lessen the possibility of reducing data obtained at various altitudes to a single curve.

Performance data obtained at a flight Mach number of 0.21 at altitudes from 5000 to 50,000 feet are presented in figure 6 to show the effect of altitude on the corrected values of net thrust, air flow, fuel flow, specific fuel consumption, fuel-air ratio, and exhaust-gas total temperature.

The variation of corrected net thrust with altitude was sufficiently small that data obtained at all altitudes from 5000 to 50,000 feet could be represented by a single curve (fig. 6(a)). The corrected engine air flow (fig. 6(b)) decreased as the altitude was increased at corrected engine speeds above 5400 rpm. For corrected engine speeds below 5400 rpm, the data appear to reduce to a single curve.

Generalized performance parameters depending on fuel consumption formed a single curve only near maximum engine speed and at altitudes below 35,000 feet. Above 35,000 feet and at reduced engine speeds, the corrected fuel consumption (fig. 6(c)) increased as the altitude was raised. Near maximum engine speed, the corrected specific fuel



consumption (fig. 6(d)) formed a single curve for data obtained at altitudes below 35,000 feet; however, higher corrected specific fuel consumptions were obtained at altitudes of 45,000 and 50,000 feet. At low engine speeds the trend of the data with increasing altitude was inconsistent. The corrected engine fuel-air ratio (fig. 6(e)) and the corrected exhaust-gas temperature (fig. 6(f)) increased with altitude at all corrected engine speeds; however, the increase in corrected engine fuel-air ratio was insignificant at a corrected engine speed of 7900 rpm and altitudes up to 35,000 feet.

Generalization in terms of pumping characteristics. - If a turbojet engine is considered as a pump that increases the energy level of the working fluid as it passes through the engine, the thrust may be determined by an evaluation of the energy change. This change in available energy is determined by the change in total pressure and total temperature of the air flowing through the engine. In this method of generalization, as in the method previously discussed, changes in component efficiencies including the effects of Reynolds number lessen the possibility of generalizing the data obtained at various altitudes to a single curve.

The variation of engine total-temperature ratio with engine total-pressure ratio is shown in figure 7(a) for altitudes from 5000 to 50,000 feet at a flight Mach number of 0.21 and in figure 7(b) for flight Mach numbers from 0.21 to 0.97 at an altitude of 25,000 feet. As the altitude was increased, the engine-total-temperature ratio increased at all values of engine-total-pressure ratio. The data for the range of flight Mach numbers investigated at an altitude of 25,000 feet plotted as a single curve at all engine-pressure ratios above approximately 1.4. Similar data obtained over a range of flight Mach numbers at other altitudes also formed a single curve for each altitude at engine total-pressure ratios above approximately 1.4. From the data presented in figure 7, the total pressure at the exhaust-nozzle outlet can be determined for any flight Mach number and exhaust-gas temperature at altitudes between 5000 and 50,000 feet and engine-total-pressure ratios above approximately 1.4. The jet thrust can then be calculated by use of equation (8) or (9) presented in the appendix.

#### Engine Windmilling Characteristics

The engine windmilling speed is shown in figure 8 as a function of true airspeed for altitudes from 5000 to 45,000 feet. The engine windmilling speed was unaffected by changes in altitude in the range of airspeeds investigated.

The internal drag of a windmilling turbojet engine is of interest, particularly on multiengine airplanes when it may be desirable to cruise with one or more engines inoperative. The ratio of windmilling drag to net thrust at maximum permissible engine speed is shown in figure 9 as a function of true airspeed for an altitude of 25,000 feet. The internal drag of a windmilling engine varied from 2 percent of the available net thrust at a true airspeed of 200 miles per hour to 15 percent at a true airspeed of 650 miles per hour. The desirability of blocking the inlet of an inoperative engine is apparent.

#### SUMMARY OF RESULTS

The following results were obtained from an investigation of a J47 turbojet engine in the NACA Lewis altitude wind tunnel at simulated altitudes from 5000 to 50,000 feet and simulated flight Mach numbers from 0.21 to 0.97:

1. The correction factors commonly used to generalize turbojet-engine performance can be used to predict performance for only a limited range of altitudes and corrected engine speeds.
2. From the engine pumping characteristics, jet thrust could be predicted for any desired flight Mach number and exhaust-gas temperature at altitudes from 5000 to 50,000 feet and engine-pressure ratios above approximately 1.4.
3. The temperature-limited engine speed decreased with increasing altitude, which indicated the need for a variable-area exhaust nozzle.
4. In general, the exhaust-gas temperature was reduced at all engine speeds by an increase in flight Mach number.
5. The specific fuel consumption at temperature-limited engine speed and a flight Mach number of 0.21 varied from 1.20 to 1.30 pounds per hour per pound of net thrust over the range of altitudes investigated. Minimum specific fuel consumption of 1.05 pounds per hour per pound of net thrust was obtained at an engine speed of approximately 6400 rpm at altitudes from 15,000 to 45,000 feet.
6. As the flight Mach number was increased from 0.21 to 0.97 at temperature-limited engine speed, the specific fuel consumption increased from 1.21 to 1.43 pounds per hour per pound of net thrust. At low engine speeds the increase was much larger.

7. At an altitude of 25,000 feet, the internal drag of a windmilling engine varied from 2 percent of the available net thrust at a true airspeed of 200 miles per hour to 15 percent at a true airspeed of 650 miles per hour.

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Cleveland, Ohio.

## APPENDIX - CALCULATIONS

## Symbols

The following symbols were used in the calculations and on the figures:

|       |   |
|-------|---|
| A     | cross-sectional area, sq ft   |
| B     | thrust scale reading, lb  |
| $C_j$ | jet-velocity coefficient, ratio of actual jet velocity or thrust to ideal velocity or thrust after expansion to free-stream static pressure |
| $C_t$ | ratio of hot exhaust-nozzle area to cold exhaust-nozzle area (1.01 at 1570° R)  |
| D     | external drag of installation, lb   |
| $D_r$ | exhaust-nozzle tail-rake drag, lb   |
| $D_w$ | windmilling drag, lb  |
| $F_j$ | jet thrust, lb  |
| $F_n$ | net thrust, lb  |
| f/a   | fuel-air ratio  |
| g     | acceleration due to gravity, 32.2 ft/sec <sup>2</sup>   |
| M     | flight Mach number  |
| N     | engine speed, rpm   |
| P     | total pressure, lb/sq ft absolute   |
| p     | static pressure, lb/sq ft absolute  |
| R     | gas constant, 53.3 ft-lb/(lb)(°R)   |
| T     | total temperature, °R   |
| $T_1$ | indicated temperature, °R   |

|            |  |
|------------|--|
| $t$        | static temperature, $^{\circ}\text{R}$   |
| $V$        | velocity, ft/sec   |
| $W_a$      | air flow, lb/sec   |
| $W_f$      | fuel flow, lb/hr   |
| $W_f/F_n$  | specific fuel consumption based on net thrust, lb/(hr)<br>(lb thrust)  |
| $\gamma$   | ratio of specific heats  |
| $\delta$   | ratio of tunnel static pressure $p_0$ to absolute static<br>pressure of NACA standard atmosphere at sea level                                |
| $\delta_a$ | ratio of tunnel static pressure $p_0$ to absolute static<br>pressure of NACA standard atmosphere at desired altitude                         |
| $\theta$   | ratio of absolute equivalent ambient static temperature to<br>absolute static temperature of NACA standard atmosphere<br>at sea level        |
| $\theta_a$ | ratio of absolute equivalent ambient static temperature to<br>absolute static temperature of NACA standard atmosphere<br>at desired altitude |

## Subscripts:

|   |  |
|---|--|
| 0 | free-air stream                          |
| 1 | engine inlet                             |
| 6 | turbine outlet                           |
| 7 | 1 inch upstream of exhaust-nozzle outlet |
| 8 | exhaust-nozzle outlet                    |
| e | equivalent                               |
| r | venturi throat rake in make-up air duct  |
| s | scale                                    |
| x | inlet duct at frictionless slip joint    |

## Methods of Calculation

Flight Mach number. - Complete ram-pressure recovery at the engine inlet was assumed. The flight Mach number was then determined from the following expression:

$$M_0 = \sqrt{\frac{2}{\gamma-1} \left[ \left( \frac{P_1}{P_0} \right)^{\frac{\gamma-1}{\gamma}} - 1 \right]} \quad (1)$$

Temperatures. - Total temperature was obtained from indicated temperature by the use of an experimentally determined thermocouple impact-recovery factor of 0.85 in the following equation:

$$T = \frac{T_1 \left( \frac{P}{P} \right)^{\frac{\gamma-1}{\gamma}}}{1 + 0.85 \left[ \left( \frac{P}{P} \right)^{\frac{\gamma-1}{\gamma}} - 1 \right]} \quad (2)$$

Equivalent temperature. - Equivalent temperature was obtained from tunnel static pressure and engine-inlet total pressure and temperature.

$$t_e = \frac{T_1}{\left( \frac{P_1}{P_0} \right)^{\frac{\gamma-1}{\gamma}}} \quad (3)$$

Air flow. - Engine air flow was calculated from pressure and temperature measurements obtained at the engine inlet (station 1) by use of the equation

$$W_a = A_1 P_1 \sqrt{\frac{2\gamma g}{t_1 R(\gamma-1)} \left[ \left( \frac{P_1}{P_1} \right)^{\frac{\gamma-1}{\gamma}} - 1 \right]} \quad (4)$$

Air-flow values obtained from measurements in the venturi of the inlet-air duct and at the exhaust nozzle agreed within 3 percent with those obtained from measurements at the engine inlet.

Thrust. - The thrust of the installation was independently determined from balance-scale measurements and also from pressures and temperatures measured near the exhaust-nozzle outlet by means of a survey rake. Because of the inefficiency of the exhaust nozzle, the scale thrust is less than the rake thrust.

Jet thrust was determined from balance-scale measurements by the use of the following equation:

$$F_{j,s} = D + B + D_r + \frac{W_a V_x}{g} + A_x (p_x - p_0) \quad (5)$$

Net thrust is then given by the equation

$$F_{n,s} = F_{j,s} - \frac{W_a}{g} V_e \quad (6)$$

The last two terms of equation (5) represent the momentum and the pressure forces on the installation at the slip joint in the inlet-air duct. The drag of the installation was determined by runs with the engine inoperative and with a blocking plate installed in the inlet to prevent air flow through the engine.

The rake thrust, which is the ideal thrust available, is given by the following equation and values obtained at station 7, 1 inch upstream of the nozzle outlet:

$$F_{j,r} = \frac{2C_t A_7 p_7 \gamma_7}{\gamma_7 - 1} \left[ \left( \frac{p_7}{p_8} \right)^{\frac{\gamma_8 - 1}{\gamma_8}} - 1 \right] + C_t A_7 (p_7 - p_0) \quad (7)$$

Alternate thrust equation. - When the assumption is made that  $p_7 = p_8$ , an alternate equation for jet thrust is as follows:

$$F_j = \frac{2\gamma_8}{\gamma_8-1} C_t A_8 p_8 \left[ \left( \frac{p_8}{p_0} \right)^{\frac{\gamma_8-1}{\gamma_8}} - 1 \right] + A_8 C_t (p_8 - p_0) \quad (8)$$

where

$$p_8 = \frac{p_8}{\left( \frac{\gamma_8+1}{2} \right)^{\frac{\gamma_8}{\gamma_8-1}}}$$

and for supersonic jet velocities where

$$\frac{p_8}{p_0} > 1.9$$

For subsonic jet velocities where

$$\frac{p_8}{p_0} < 1.9$$

equation (8) reduces to

$$F_j = \frac{2\gamma_8 A_8 p_0 C_t}{\gamma_8-1} \left[ \left( \frac{p_8}{p_0} \right)^{\frac{\gamma_8-1}{\gamma_8}} - 1 \right] \quad (9)$$



REFERENCE

1. Sanders, Newell D.: Performance Parameters for Jet-Propulsion Engines. NACA TN 1106, 1946.

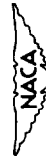
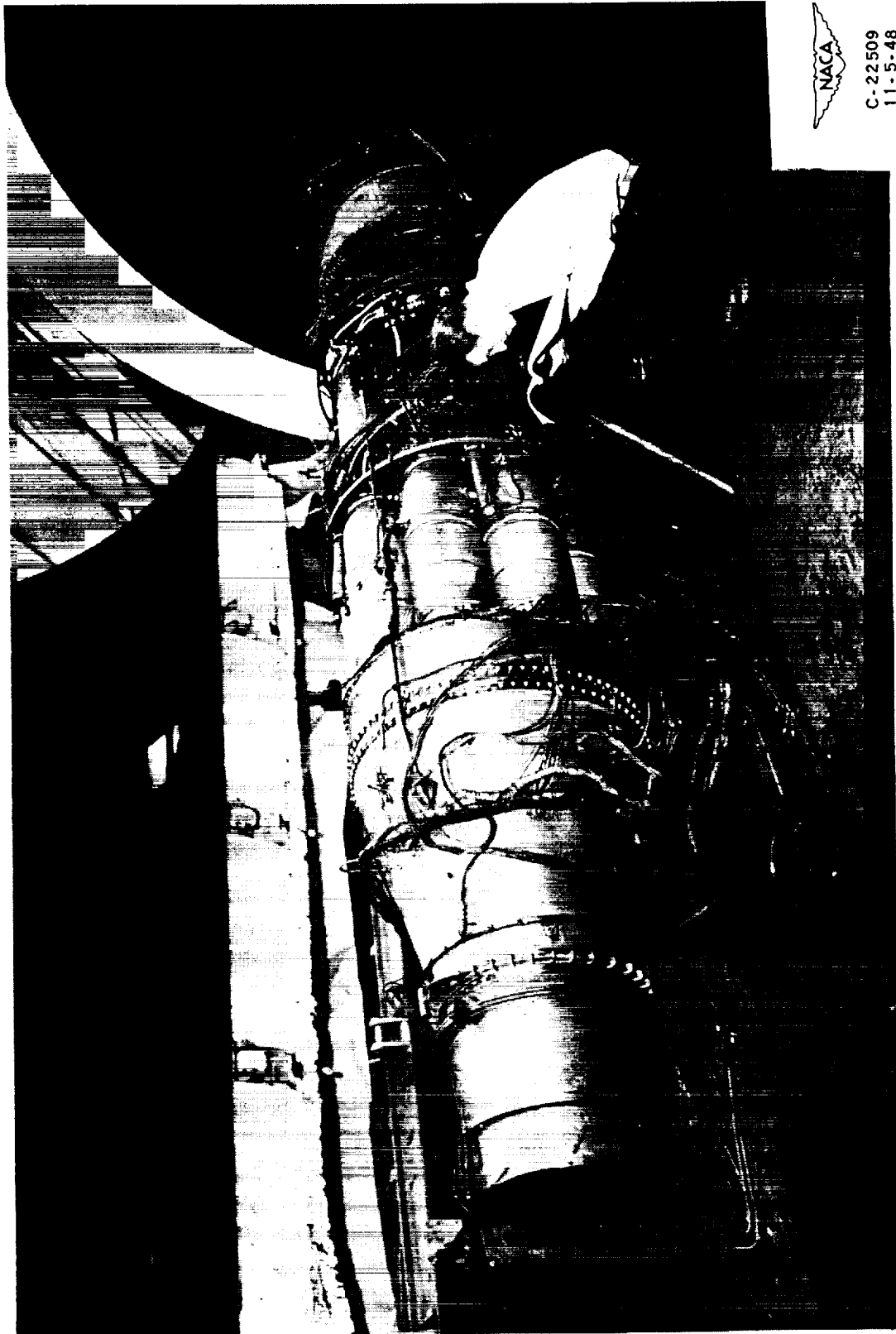
TABLE I - ENGINE PERFORMANCE DATA

| Run | Altitude<br>(ft) | Ham-pressure ratio<br>$P_1/P_0$ | Flight Mach number<br>$M$ | Tunnel static pressure<br>$P_0$ (lb/sq ft abs.) | Equivalent ambient tem-<br>perature, $t_a$ (°R) | Engine speed, $N$<br>(rpm) | Compressor-inlet<br>indicated temperature<br>$T_{1,1}$ (°R) | Net thrust, $F_j$<br>(lb) | Net thrust, $F_n$<br>(lb) | Engine-inlet air flow<br>$\dot{W}_{a,1}$ (lb/sec) | Fuel flow, $\dot{W}_f$<br>(lb/hr) | Specific fuel consumption<br>based on net thrust<br>$F_j/F_n$ (lb/hr)(lb thrust) | Fuel-air ratio<br>$F/A$ | Exhaust-gas total tem-<br>perature, $T_4$ (°R) | Turbine-outlet total pres-<br>sure, $P_6$ (lb/sq ft abs.) | Corrected engine speed<br>$N/\theta$ (rpm) | Corrected net thrust<br>$F/\theta$ (lb) | Corrected engine-inlet<br>air flow, $\dot{W}_{a,1}/\theta$<br>(lb/sec) | Corrected fuel con-<br>sumption, $W_f/(\theta W_{a,1})$<br>(lb/hr) | Corrected specific fuel<br>consumption based on net<br>thrust, $W_f/(F_n \theta)$<br>(lb/hr)(lb thrust) | Corrected fuel-air<br>ratio, $(F/A)/\theta$ | Corrected exhaust-gas<br>total temperature, $T_4/\theta$ (°R) | Engine total-pressure<br>ratio, $P_1/P_1$ | Engine total-temperature<br>ratio, $T_4/T_1$ |       |
|-----|------------------|---------------------------------|---------------------------|---|---|----------------------------|---|---------------------------|---------------------------|---|-----------------------------------|--|-------------------------|--|---|--|---|--|--|---|---|---|---|--|-------|
| 1   | 5,000            | 1.038                           | 0.230                     | 1740  | 507   | 7895                       | 509   | 4880                      | 4237                      | 81.08   | 5300                              | 1.213  | 0.0182                  | 1740   | 3465  | 7990                                       | 5150                                    | 97.42  | 6523   | 1.265   | 0.0186                                      | 1780  | 1.865                                     | 3.398  |       |
| 2   | 5,000            | 1.037                           | 0.225                     | 1756  | 507   | 7692                       | 511   | 4593                      | 3957                      | 81.07   | 4800                              | 1.213  | 0.0164                  | 1631   | 3352  | 7769                                       | 4770                                    | 96.72  | 5842   | 1.225   | 0.0167                                      | 1665  | 1.865                                     | 3.398  |       |
| 3   | 5,000            | 1.039                           | 0.230                     | 1740  | 506   | 7500                       | 510   | 4305                      | 3660                      | 80.28   | 4390                              | 1.198  | 0.0152                  | 1542   | 3247  | 7598                                       | 4455                                    | 96.37  | 5408   | 1.213   | 0.0156                                      | 1583  | 1.790                                     | 3.173  |       |
| 4   | 5,000            | 1.036                           | 0.220                     | 1742  | 508   | 6983                       | 511   | 3650                      | 3053                      | 76.94   | 3550                              | 1.162  | 0.0128                  | 1396   | 2984  | 7070                                       | 3720                                    | 92.46  | 4359   | 1.175   | 0.0130                                      | 1426  | 1.605                                     | 2.721  |       |
| 5   | 5,000            | 1.034                           | 0.215                     | 1742  | 507   | 6459                       | 511   | 2846                      | 2318                      | 70.23   | 2710                              | 1.168  | 0.0107                  | 1268   | 2679  | 6537                                       | 2818                                    | 84.32  | 3333   | 1.183   | 0.0109                                      | 1297  | 1.454                                     | 2.477  |       |
| 6   | 5,000            | 1.033                           | 0.210                     | 1744  | 506   | 5944                       | 510   | 2085                      | 1615                      | 63.66   | 2060                              | 1.275  | 0.0090                  | 1170   | 2403  | 6021                                       | 1962                                    | 76.23  | 2532   | 1.292   | 0.0092                                      | 1200  | 1.314                                     | 2.290  |       |
| 7   | 5,000            | 1.033                           | 0.210                     | 1740  | 505   | 5024                       | 508   | 1172                      | 817                       | 48.05   | 1350                              | 1.654  | 0.0085                  | 1096   | 2083  | 5094                                       | 994                                     | 57.62  | 1665   | 1.675   | 0.0079                                      | 1127  | 1.149                                     | 2.149  |       |
| 8   | 5,000            | 1.034                           | 0.215                     | 1749  | 504   | 4091                       | 509   | 669                       | 413                       | 34.21   | 1050                              | 2.542  | 0.0085                  | 1125   | 1924  | 4152                                       | 499                                     | 40.78  | 1289   | 2.582   | 0.0087                                      | 1160  | 1.059                                     | 2.210  |       |
| 9   | 5,000            | 1.032                           | 0.210                     | 1745  | 504   | 3147                       | 509   | 312                       | 140                       | 23.73   | 820                               | 5.857  | 0.0096                  | 1167   | 1832  | 3194                                       | 169                                     | 28.36  | 1009   | 5.940   | 0.0098                                      | 1202  | 1.017                                     | 2.293  |       |
| 10  | 5,000            | 1.032                           | 0.210                     | 1738  | 504   | 2046                       | 509   | 129                       | 10                        | 16.42   | 474                               | ---  | 0.080                   | 1134   | 1769  | 2077                                       | 12                                      | 19.69  | 585  | 48.1  | 0.082                                       | 1168  | 0.987                                     | 2.228  |       |
| 11  | 15,000           | 1.034                           | 0.215                     | 1188  | 478   | 6993                       | 480   | 2735                      | 2323                      | 56.81   | 2550                              | 1.097  | 0.0126                  | 1386   | 2102  | 7287                                       | 4137                                    | 96.42  | 4733   | 1.142   | 0.0137                                      | 1506  | 1.664                                     | 2.870  |       |
| 12  | 15,000           | 1.030                           | 0.205                     | 1188  | 479   | 6459                       | 481   | 2219                      | 1863                      | 51.80   | 2020                              | 1.065  | 0.0108                  | 1254   | 1896  | 6724                                       | 3320                                    | 88.62  | 3745   | 1.130   | 0.0117                                      | 1358  | 1.507                                     | 2.596  |       |
| 13  | 15,000           | 1.030                           | 0.205                     | 1188  | 475   | 5944                       | 478   | 1694                      | 1375                      | 46.87   | 1550                              | 1.127  | 0.0092                  | 1145   | 1707  | 6211                                       | 2450                                    | 79.54  | 2885   | 1.178   | 0.0100                                      | 1253  | 1.367                                     | 2.390  |       |
| 14  | 15,000           | 1.030                           | 0.205                     | 1186  | 471   | 5024                       | 475   | 1000                      | 755                       | 36.00   | 980                               | 1.297  | 0.0076                  | 1034   | 1541  | 5275                                       | 1430                                    | 61.17  | 1836   | 2.145   | 0.0083                                      | 1138  | 1.167                                     | 2.177  |       |
| 15  | 15,000           | 1.028                           | 0.195                     | 1190  | 471   | 4091                       | 475   | 538                       | 376                       | 24.58   | 768                               | 2.043  | 0.0087                  | 1060   | 1320  | 4296                                       | 870                                     | 41.76  | 1438   | 3.768   | 0.0095                                      | 1235  | 1.076                                     | 2.332  |       |
| 16  | 15,000           | 1.031                           | 0.205                     | 1186  | 470   | 3147                       | 474   | 304                       | 169                       | 19.42   | 605                               | 3.580  | 0.0087                  | 1119   | 1261  | 3307                                       | 300                                     | 32.85  | 1131   | 3.768   | 0.0095                                      | 1235  | 1.024                                     | 2.361  |       |
| 17  | 15,000           | 1.028                           | 0.195                     | 1188  | 468   | 2046                       | 472   | 157                       | 100                       | 8.58  | 371                               | 3.675  | 0.0120                  | 1105   | 1213  | 2154                                       | 179                                     | 14.51  | 696  | 3.870   | 0.0133                                      | 1225  | 0.992                                     | 2.341  |       |
| 18  | 15,000           | 1.204                           | 0.525                     | 1186  | 474   | 7895                       | 498   | 4016                      | 2936                      | 62.37   | 4130                              | 1.407  | 0.0184                  | 1754   | 2685  | ---  | ---                                     | ---  | ---  | ---   | ---   | ---   | ---                                       | 1.820  | 3.508 |
| 19  | 15,000           | 1.210                           | 0.530                     | 1186  | 477   | 7692                       | 502   | 3912                      | 2776                      | 64.50   | 3730                              | 1.344  | 0.0161                  | 1614   | 2625  | ---  | ---                                     | ---  | ---  | ---   | ---   | ---   | ---                                       | 1.781  | 3.202 |
| 20  | 15,000           | 1.211                           | 0.530                     | 1186  | 480   | 7500                       | 505   | 3698                      | 2563                      | 64.09   | 3395                              | 1.324  | 0.0147                  | 1544   | 2549  | ---  | ---                                     | ---  | ---  | ---   | ---   | ---   | ---                                       | 1.719  | 3.045 |
| 21  | 15,000           | 1.205                           | 0.525                     | 1190  | 480   | 6993                       | 504   | 3210                      | 2132                      | 61.72   | 2720                              | 1.275  | 0.0122                  | 1362   | 2334  | ---  | ---                                     | ---  | ---  | ---   | ---   | ---   | ---                                       | 1.577  | 2.692 |
| 22  | 15,000           | 1.203                           | 0.520                     | 1188  | 482   | 6459                       | 506   | 2450                      | 1441                      | 56.77   | 1990                              | 1.380  | 0.0097                  | 1200   | 2039  | ---  | ---                                     | ---  | ---  | ---   | ---   | ---   | ---                                       | 1.383  | 2.362 |
| 23  | 15,000           | 1.203                           | 0.520                     | 1190  | 480   | 5944                       | 505   | 1753                      | 869                       | 50.82   | 1380                              | 1.590  | 0.0075                  | 1058   | 1765  | ---  | ---                                     | ---  | ---  | ---   | ---   | ---   | ---                                       | 1.212  | 2.091 |
| 24  | 15,000           | 1.204                           | 0.525                     | 1185  | 479   | 5024                       | 504   | 904                       | 227                       | 38.87   | 770                               | 3.392  | 0.0055                  | 914  | 1458  | ---  | ---                                     | ---  | ---  | ---   | ---   | ---   | ---                                       | 1.015  | 1.810 |
| 25  | 15,000           | 1.203                           | 0.520                     | 1190  | 481   | 4091                       | 506   | 419                       | 68                        | 27.95   | 549                               | ---  | 0.0055                  | 880  | 1340  | ---  | ---                                     | ---  | ---  | ---   | ---   | ---   | ---                                       | 0.929  | 1.736 |
| 26  | 15,000           | 1.203                           | 0.520                     | 1190  | 478   | 3147                       | 503   | 197                       | 185                       | 21.99   | 361                               | ---  | 0.0046                  | 801  | 1258  | ---  | ---                                     | ---  | ---  | ---   | ---   | ---   | ---                                       | 0.876  | 1.589 |
| 27  | 25,000           | 1.037                           | 0.225                     | 777   | 447   | 7692                       | 450   | 2409                      | 2127                      | 38.38   | 2610                              | 1.228  | 0.0189                  | 1783   | 1661  | 8284                                       | 5790                                    | 97.04  | 7654   | 1.323   | 0.0218                                      | 2067  | 1.990                                     | 3.945  |       |
| 28  | 25,000           | 1.036                           | 0.220                     | 774   | 450   | 7500                       | 453   | 2175                      | 1895                      | 38.02   | 2200                              | 1.162  | 0.0161                  | 1580   | 1549  | 8055                                       | 5181                                    | 96.78  | 6460   | 1.247   | 0.0187                                      | 1820  | 1.872                                     | 3.473  |       |
| 29  | 25,000           | 1.036                           | 0.220                     | 777   | 451   | 6993                       | 454   | 1876                      | 1603                      | 37.39   | 1780                              | 1.111  | 0.0132                  | 1388   | 1433  | 7503                                       | 4360                                    | 94.89  | 5201   | 1.191   | 0.0152                                      | 1598  | 1.735                                     | 3.044  |       |
| 30  | 25,000           | 1.033                           | 0.210                     | 779   | 451   | 6459                       | 453   | 1565                      | 1318                      | 35.39   | 1420                              | 1.077  | 0.0111                  | 1244   | 1310  | 6931                                       | 3580                                    | 89.58  | 4159   | 1.156   | 0.0128                                      | 1430  | 1.589                                     | 2.734  |       |
| 31  | 25,000           | 1.033                           | 0.210                     | 778   | 452   | 5944                       | 455   | 1178                      | 955                       | 31.96   | 1070                              | 1.120  | 0.0093                  | 1121   | 1155  | 6366                                       | 2597                                    | 81.17  | 3115   | 1.200   | 0.0107                                      | 1287  | 1.412                                     | 2.458  |       |
| 32  | 25,000           | 1.031                           | 0.205                     | 778   | 451   | 5024                       | 455   | 598                       | 431                       | 24.64   | 702                               | 1.630  | 0.0079                  | 1011   | 972   | 5391                                       | 1172                                    | 62.46  | 2048   | 1.747   | 0.0091                                      | 1163  | 1.203                                     | 2.222  |       |
| 33  | 25,000           | 1.030                           | 0.205                     | 777   | 452   | 4091                       | 455   | 305                       | 184                       | 18.10   | 560                               | 3.043  | 0.0066                  | 1034   | 870   | 4381                                       | 501                                     | 46.02  | 1633   | 3.259   | 0.0099                                      | 1188  | 1.062                                     | 2.268  |       |
| 34  | 25,000           | 1.030                           | 0.205                     | 774   | 452   | 3147                       | 456   | 159                       | 77                        | 12.24   | 440                               | 5.710  | 0.0100                  | 1095   | 815   | 3370                                       | 210                                     | 31.25  | 1288   | 6.120   | 0.0115                                      | 1258  | 1.022                                     | 2.401  |       |
| 35  | 25,000           | 1.207                           | 0.525                     | 781   | 441   | 7895                       | 466   | 3017                      | 2270                      | 44.26   | 3025                              | 1.532  | 0.0117                  | 1182   | 790   | 2195                                       | 59                                      | 22.17  | 1074   | 17.89   | 0.0135                                      | 1323  | 0.996                                     | 2.532  |       |
| 36  | 25,000           | 1.207                           | 0.525                     | 774   | 444   | 7692                       | 463   | 2884                      | 2136                      | 44.25   | 2725                              | 1.277  | 0.0100                  | 1095   | 815   | 3370                                       | 210                                     | 31.25  | 1288   | 6.120   | 0.0115                                      | 1258  | 1.022                                     | 2.401  |       |
| 37  | 25,000           | 1.208                           | 0.530                     | 774   | 441   | 7692                       | 463   | 2884                      | 2136                      | 44.25   | 2725                              | 1.277  | 0.0100                  | 1095   | 815   | 3370                                       | 210                                     | 31.25  | 1288   | 6.120   | 0.0115                                      | 1258  | 1.022                                     | 2.401  |       |
| 38  | 25,000           | 1.211                           | 0.530                     | 774   | 432   | 7500                       | 454   | 2771                      | 2012                      | 45.17   | 2550                              | 1.267  | 0.0100                  | 1095   | 815   | 3370                                       | 210                                     | 31.25  | 1288   | 6.120   | 0.0115                                      | 1258  | 1.022                                     | 2.401  |       |
| 39  | 25,000           | 1.213                           | 0.535                     | 774   | 431   | 6993                       | 454   | 2470                      | 1724                      | 44.24   | 2030                              | 1.178  | 0.0100                  | 1095   | 815   | 3370                                       | 210                                     | 31.25  | 1288   | 6.120   | 0.0115                                      | 1258  | 1.022                                     | 2.401  |       |

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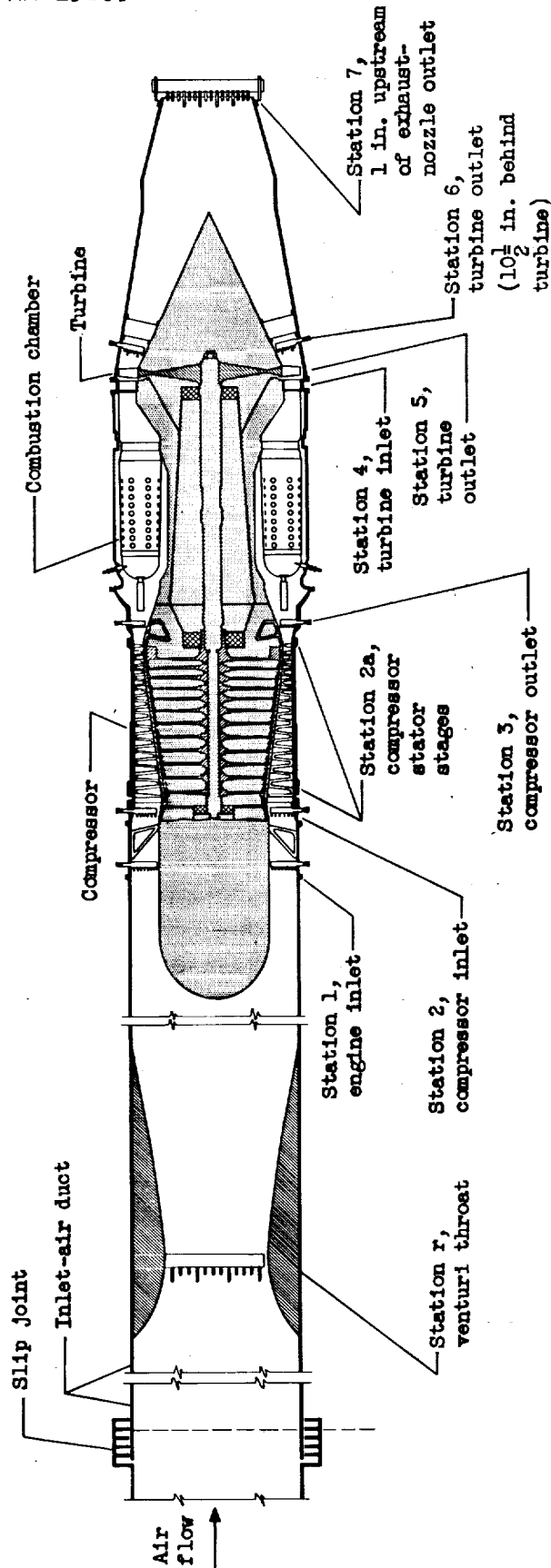




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Figure 1. - View of J47 turbojet engine installed in test section of altitude wind tunnel.





| Station | Total pressure tubes | Static-pressure tubes | Wall static-pressure orifices | Thermo-couples |
|---------|----------------------|-----------------------|-------------------------------|----------------|
| r       | 12                   | 4                     | 4                             | 6              |
| 1       | 40                   | 4                     | 0                             | 8              |
| 2       | 24                   | 0                     | 4                             | 0              |
| 2a      | 0                    | 0                     | 13                            | 0              |
| 3       | 20                   | 0                     | 4                             | 6              |
| 4       | 5                    | 0                     | 0                             | 0              |
| 5       | 0                    | 0                     | 0                             | 8              |
| 6       | 30                   | 0                     | 2                             | 33             |
| 7       | 18                   | 5                     | 4                             | 14             |

Figure 2. - Cross section of turbojet-engine installation showing sections at which instrumentation was installed.



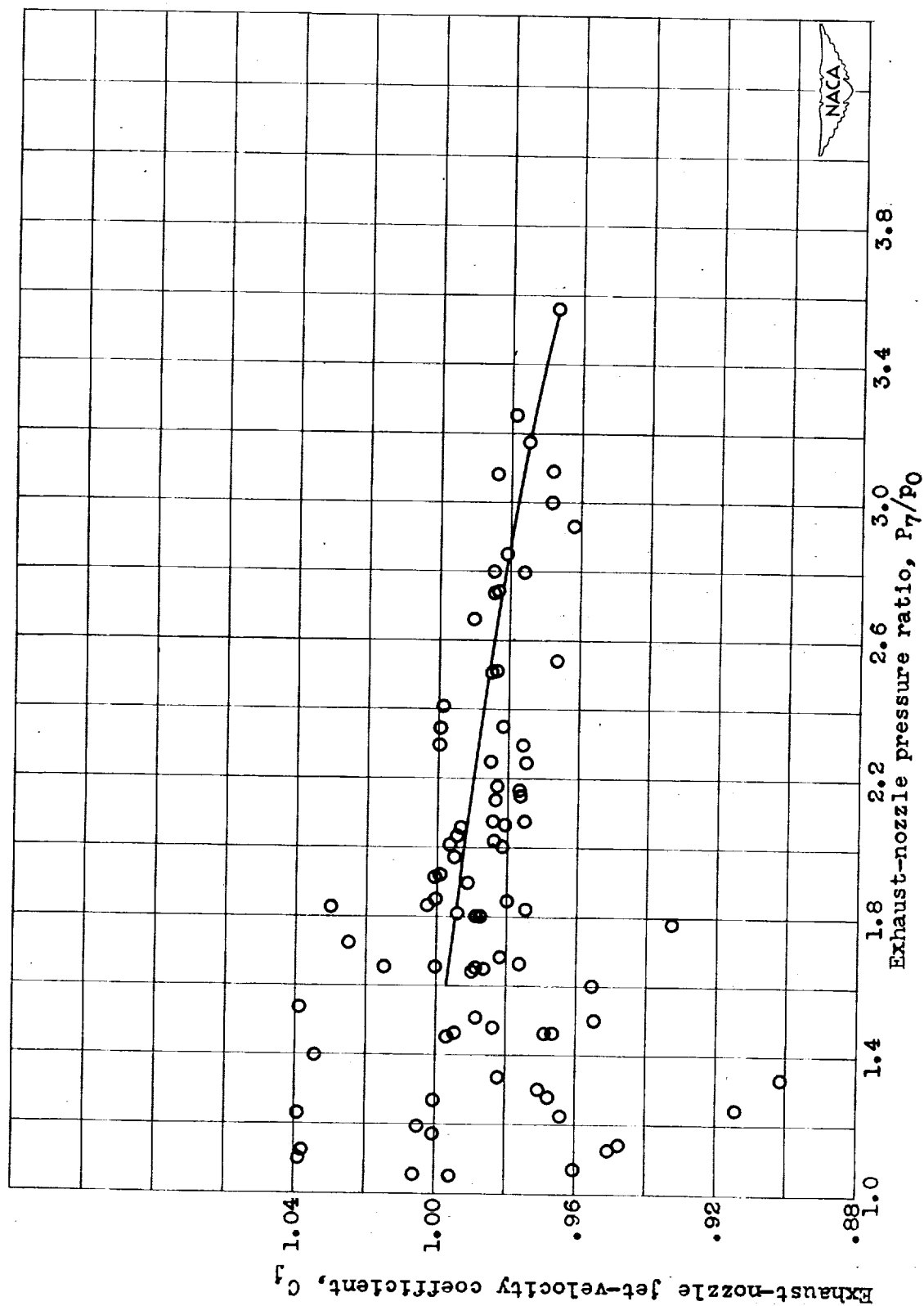
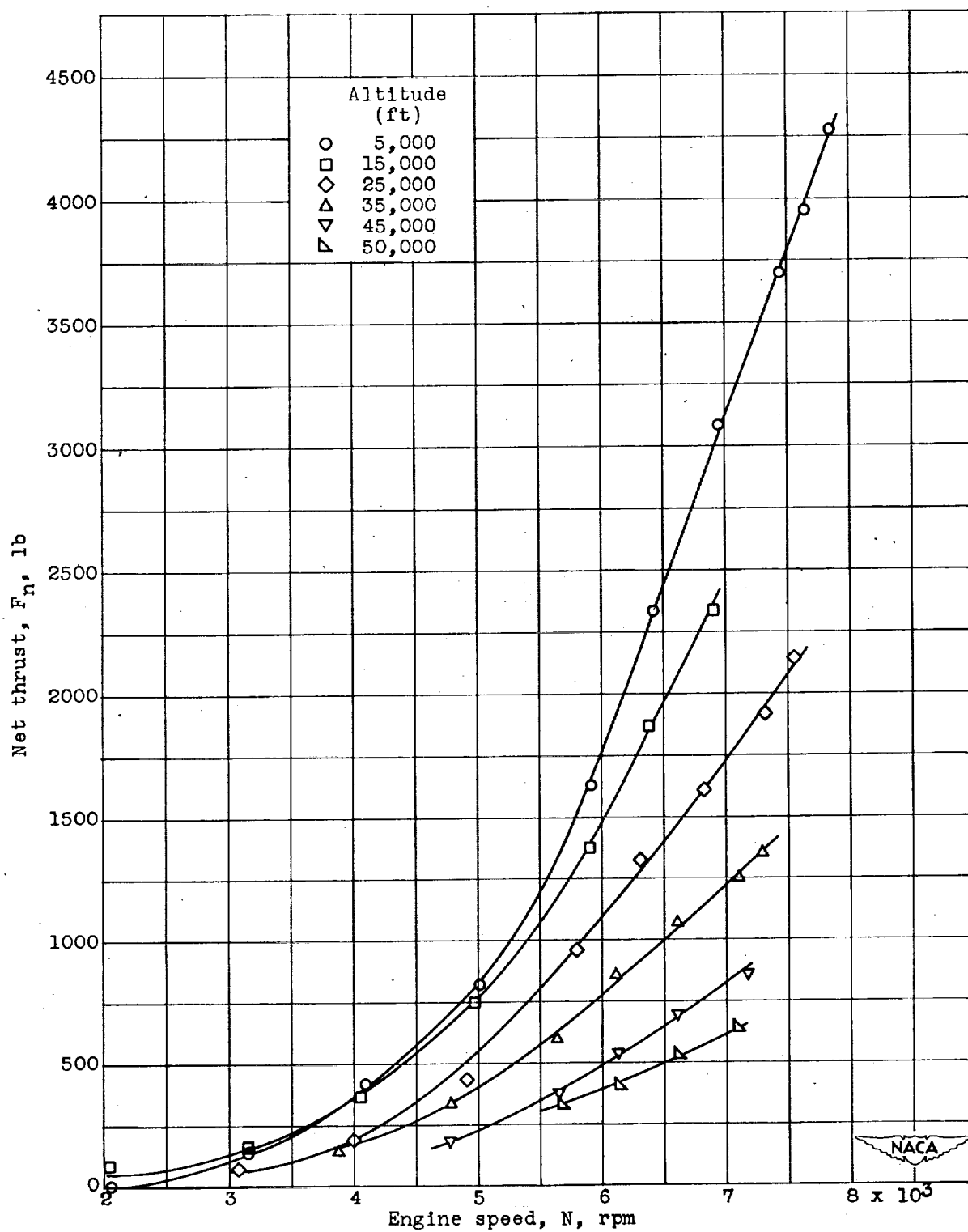


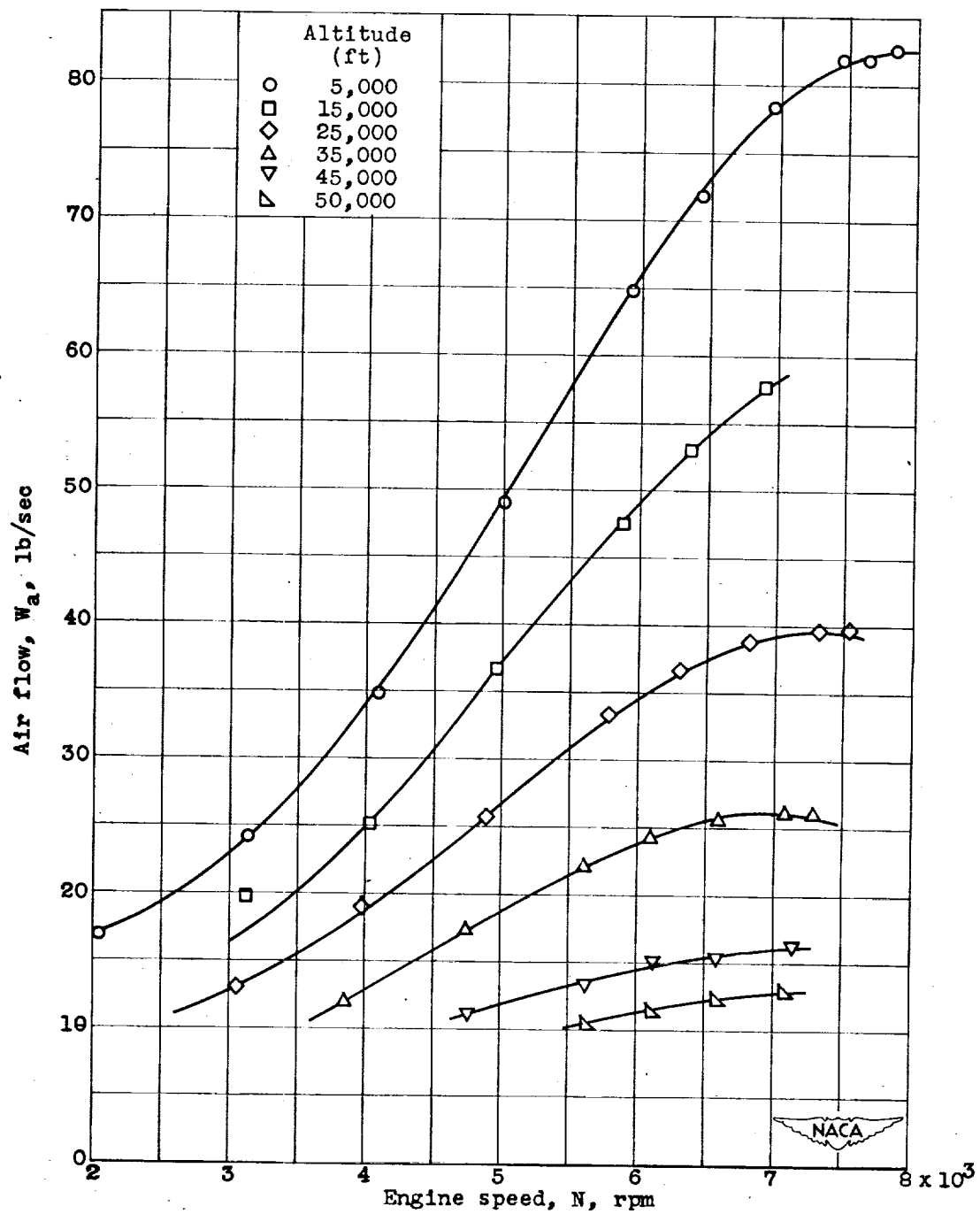
Figure 3. - Variation of exhaust-nozzle jet-velocity coefficient with exhaust-nozzle pressure ratio.





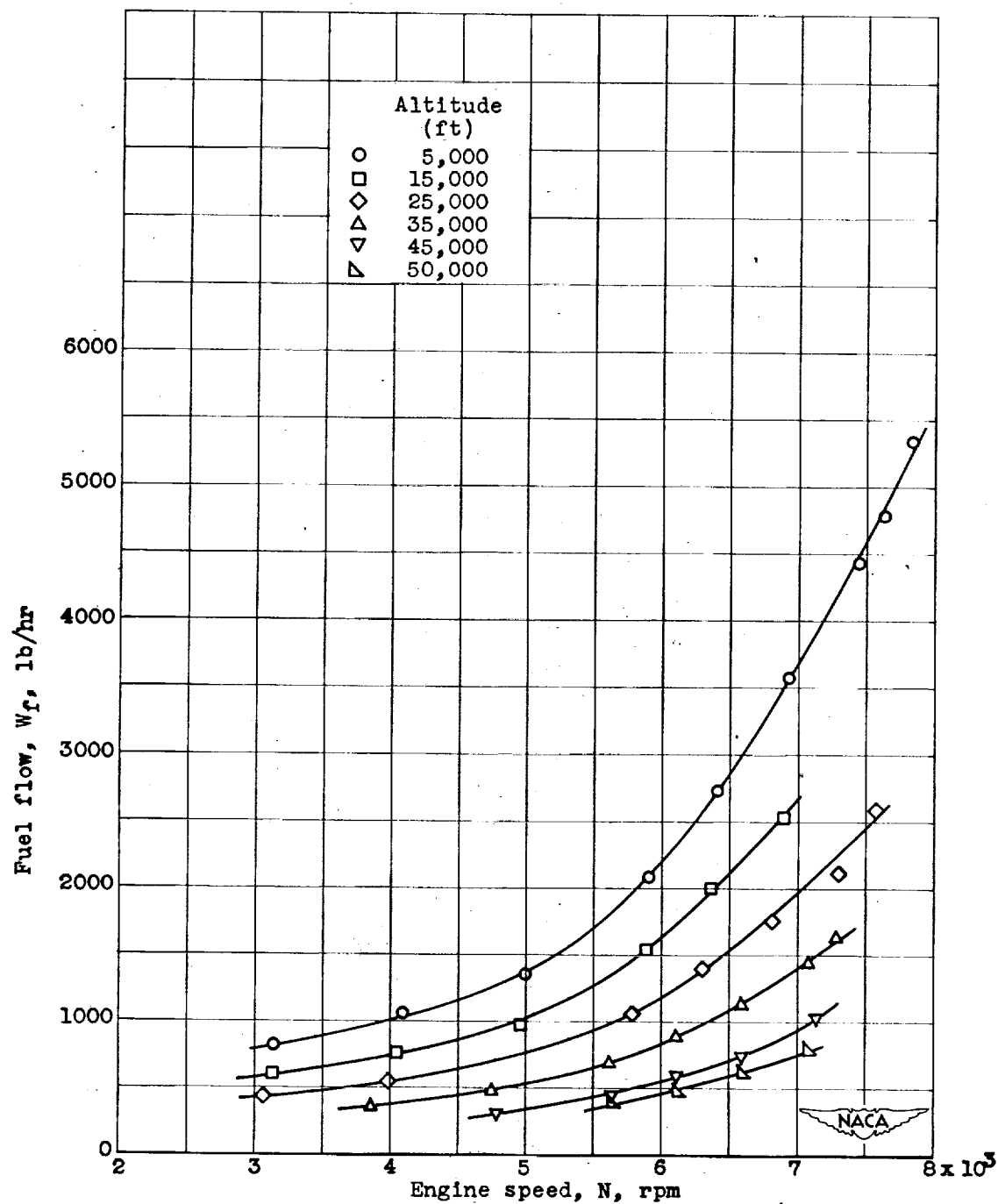
(a) Net thrust.

Figure 4. - Effect of altitude on variation of engine performance with engine speed at flight Mach number of 0.21.



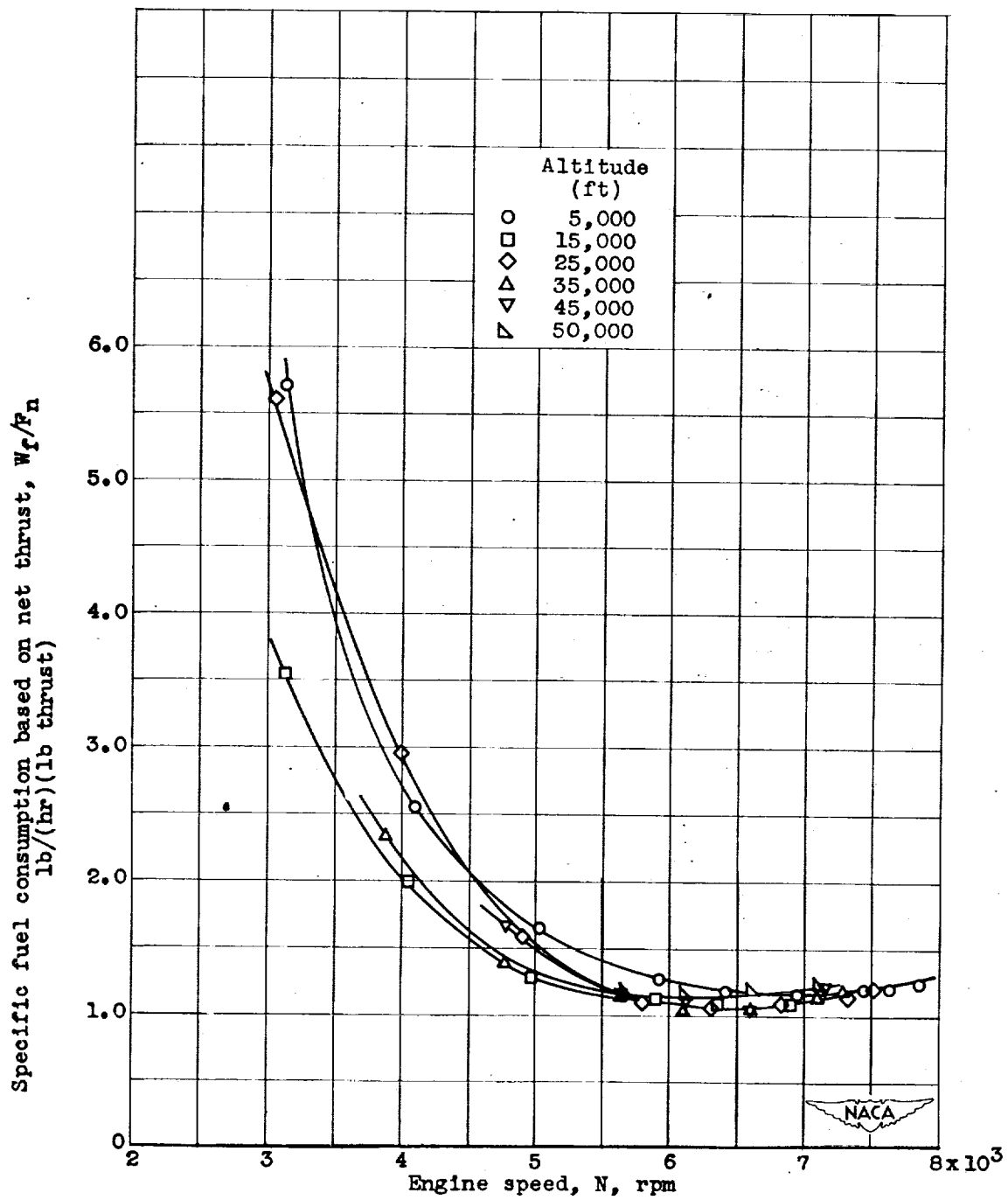
(b) Air flow.

Figure 4. - Continued. Effect of altitude on variation of engine performance with engine speed at flight Mach number of 0.21.



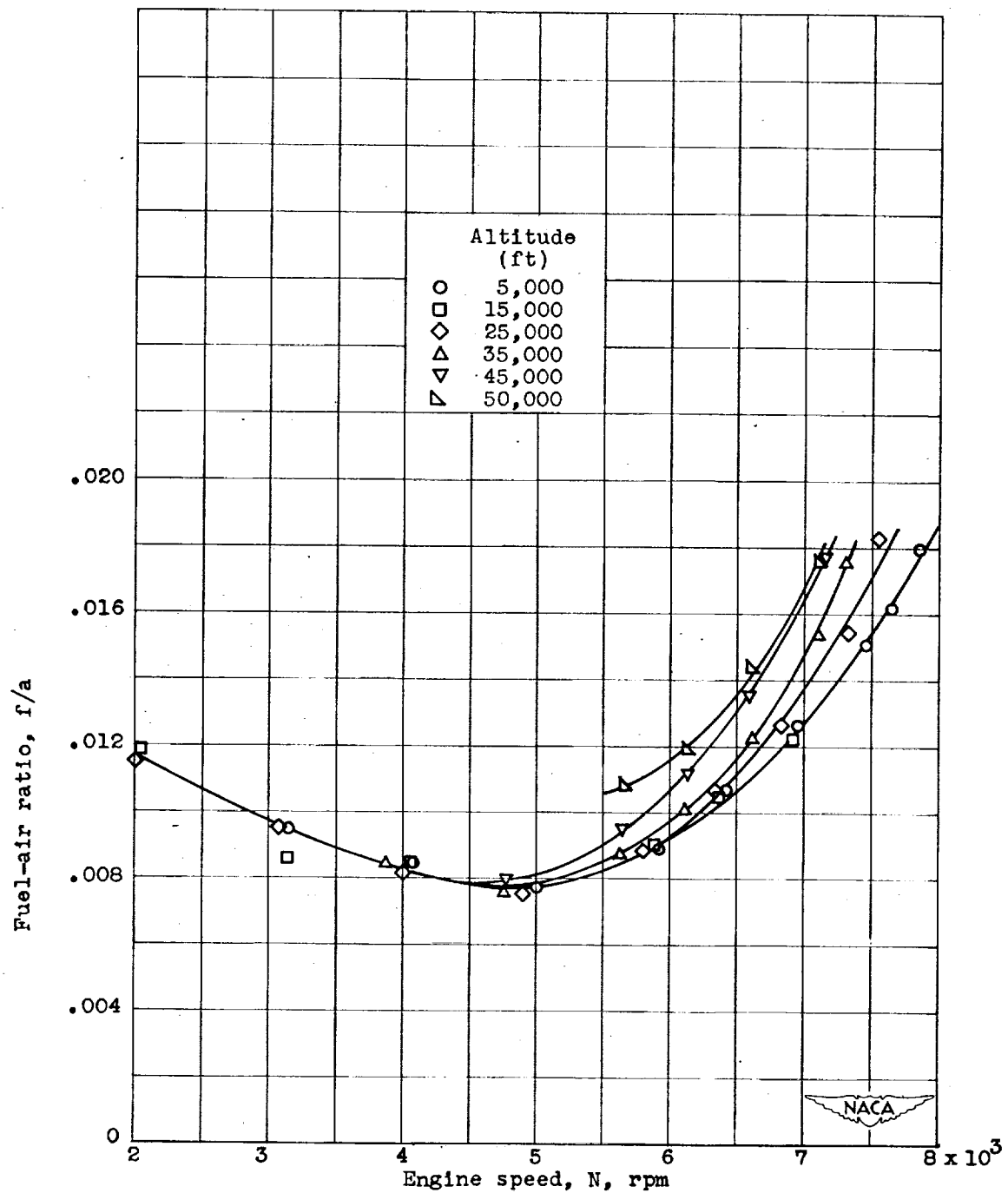
(c) Fuel flow.

Figure 4. - Continued. Effect of altitude on variation of engine performance with engine speed at flight Mach number of 0.21.



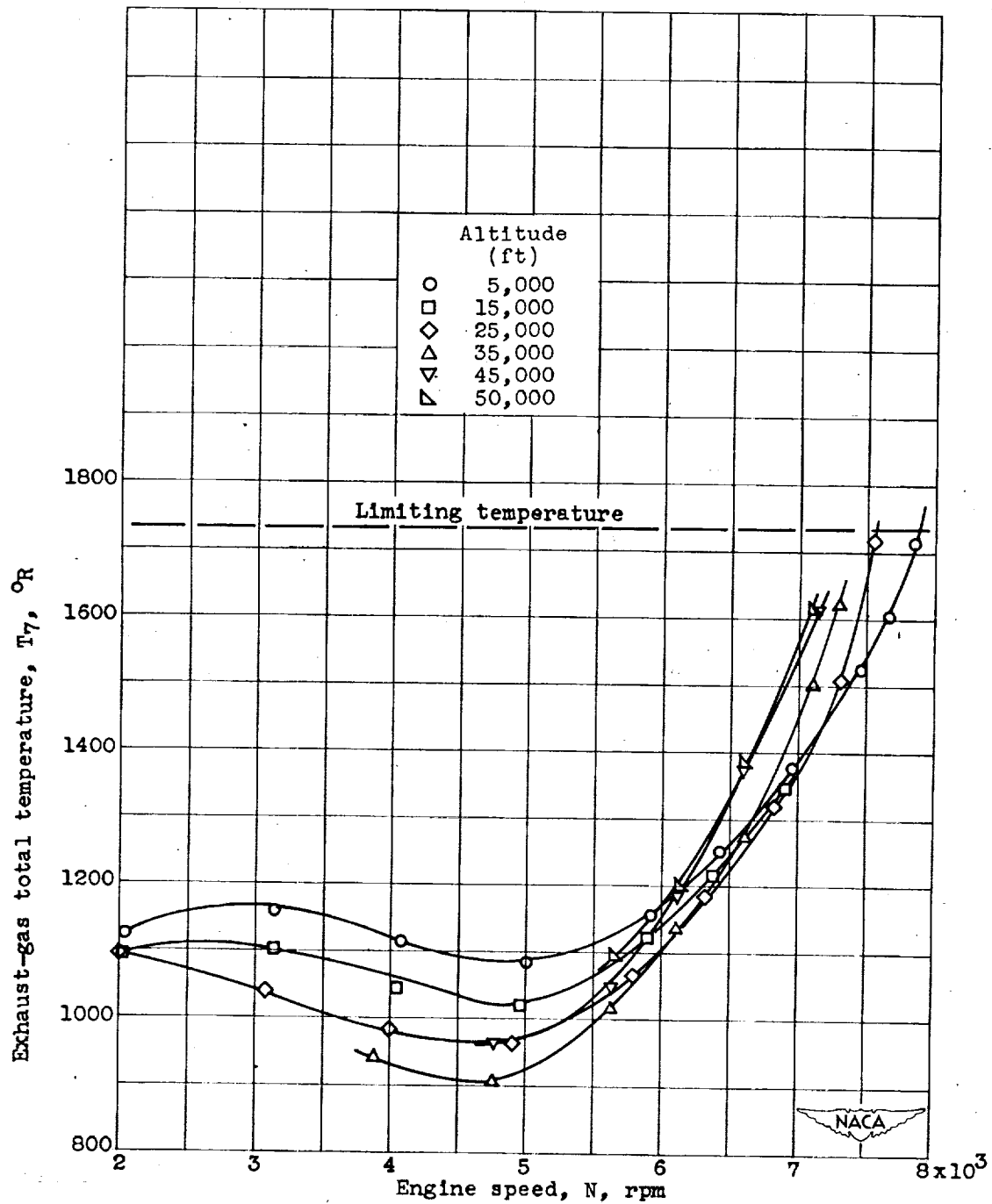
(d) Specific fuel consumption

Figure 4. - Continued. Effect of altitude on variation of engine performance with engine speed at flight Mach number of 0.21.



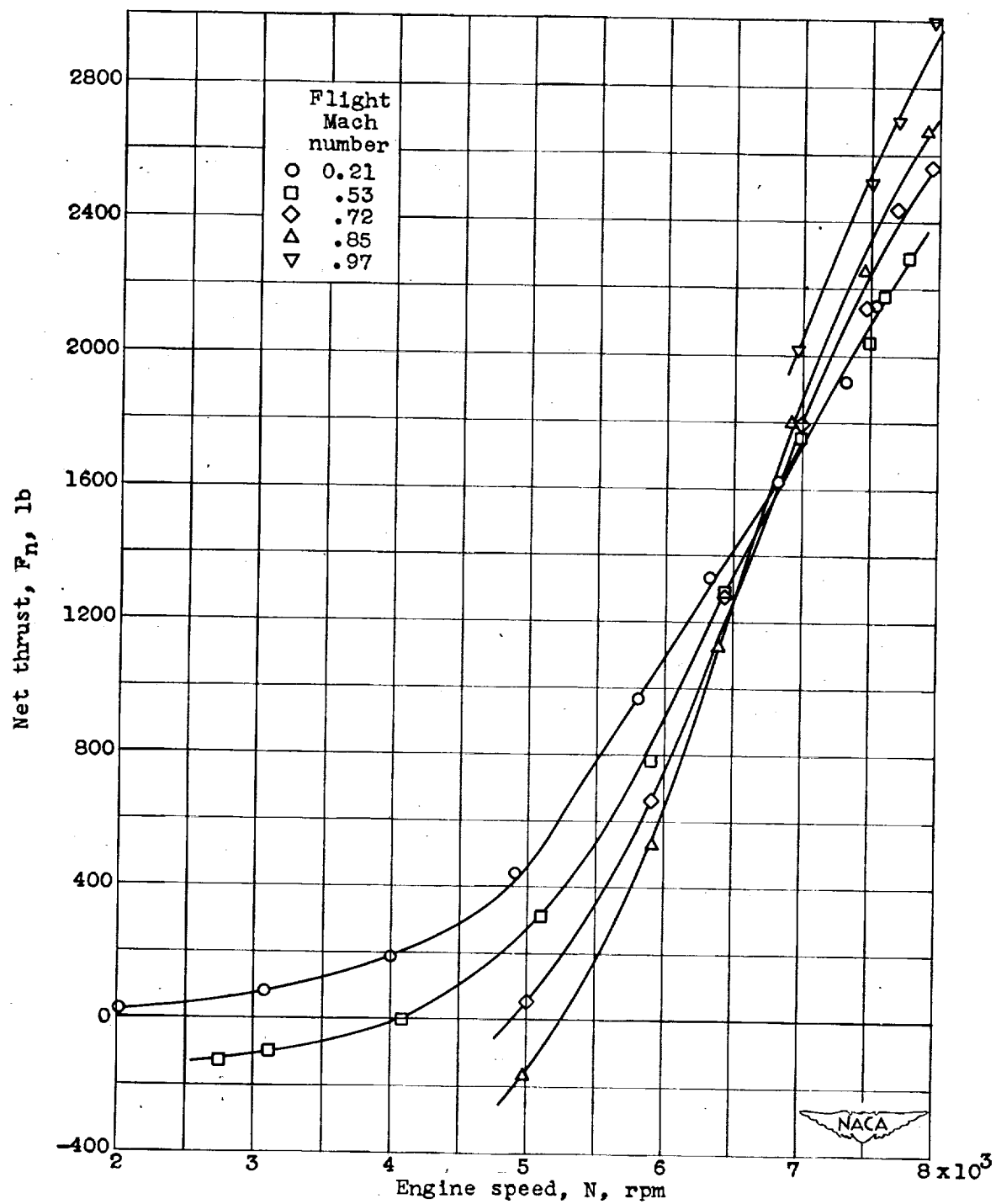
(e) Fuel-air ratio.

Figure 4. - Continued. Effect of altitude on variation of engine performance with engine speed at flight Mach number of 0.21.



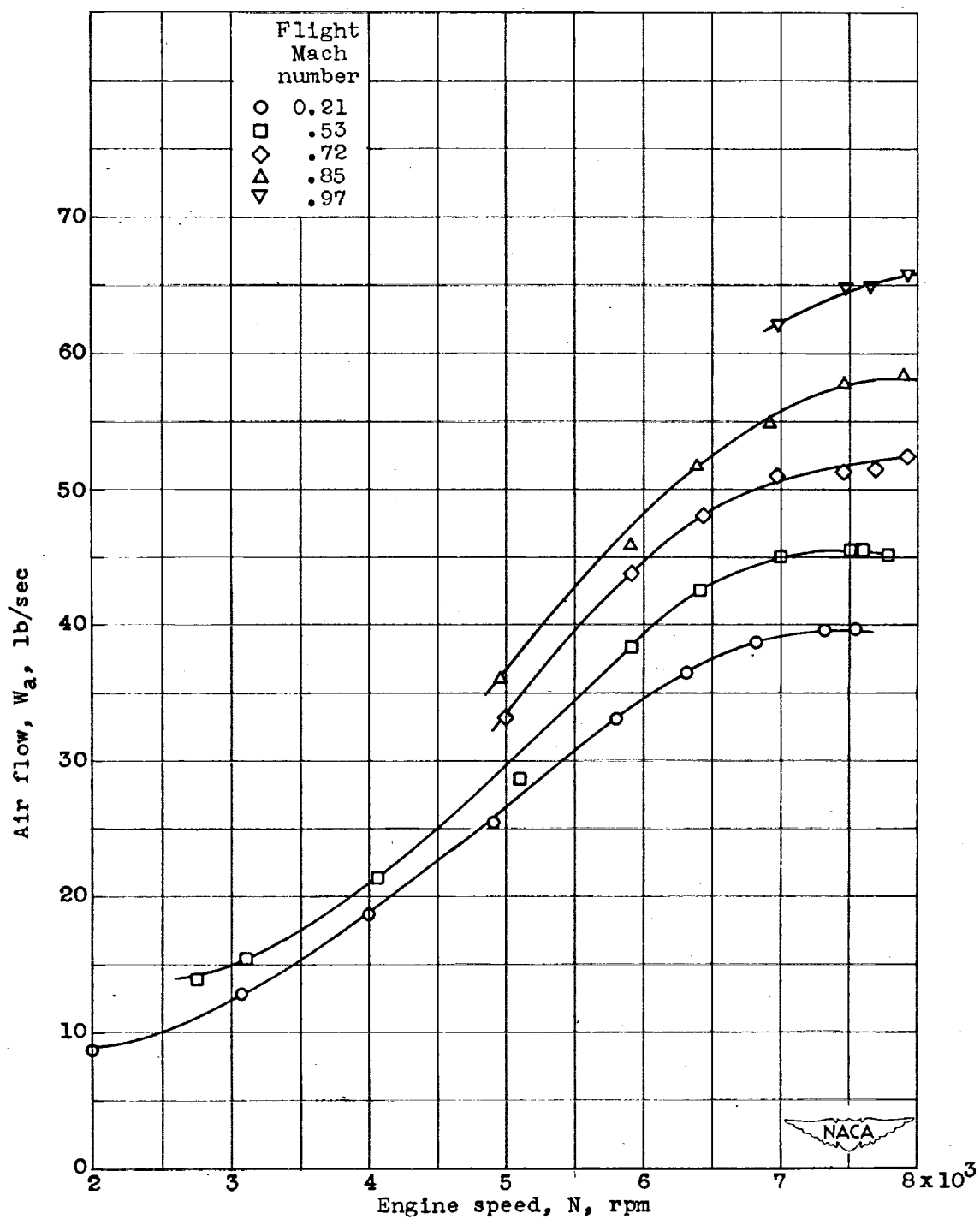
(f) Exhaust-gas total temperature.

Figure 4. - Concluded. Effect of altitude on variation of engine performance with engine speed at flight Mach number of 0.21.



(a) Net thrust.

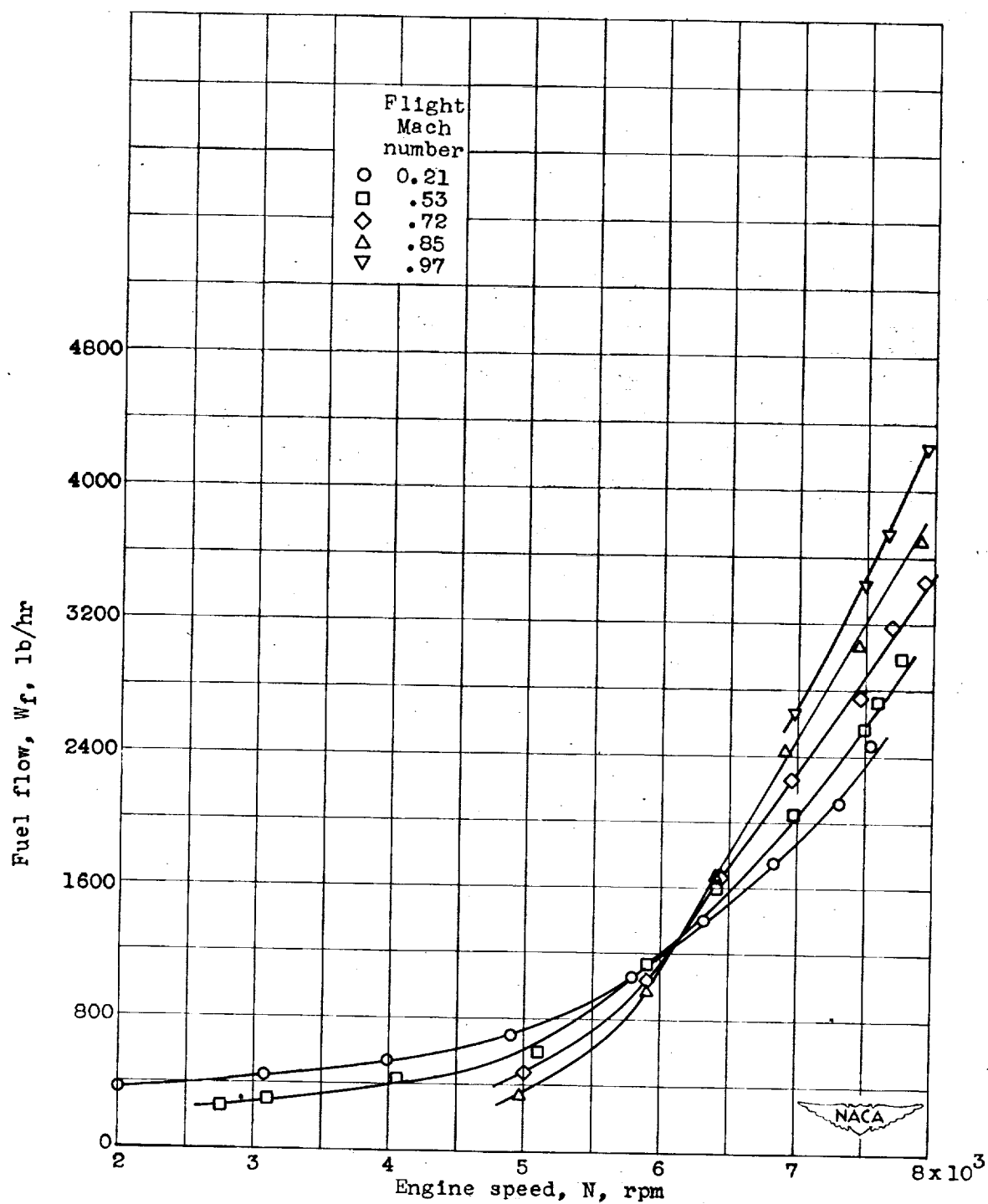
Figure 5. - Effect of flight Mach number on variation of engine performance with engine speed at altitude of 25,000 feet.



(b) Air flow.

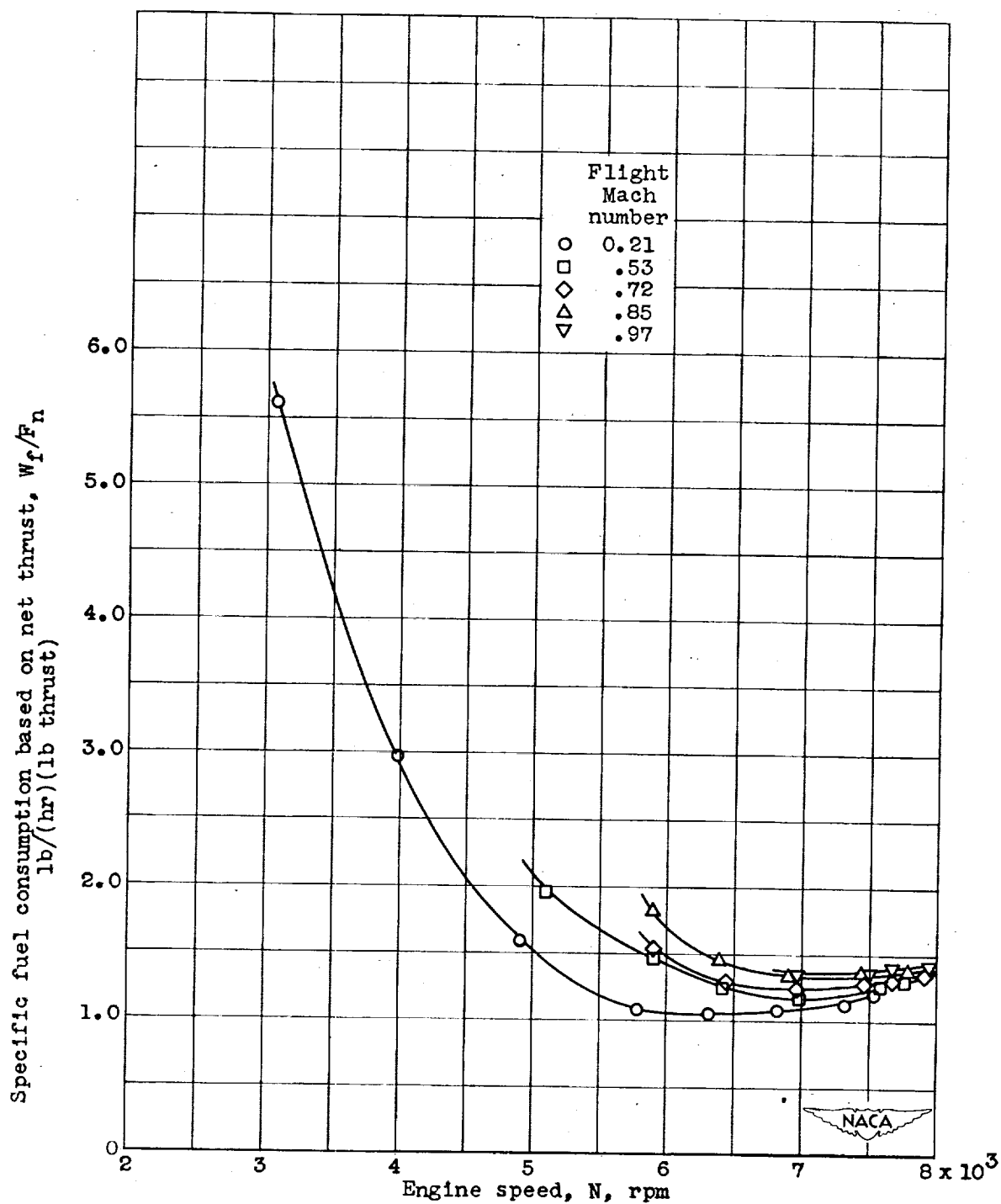
Figure 5. - Continued. Effect of flight Mach number on variation of engine performance with engine speed at altitude of 25,000 feet.





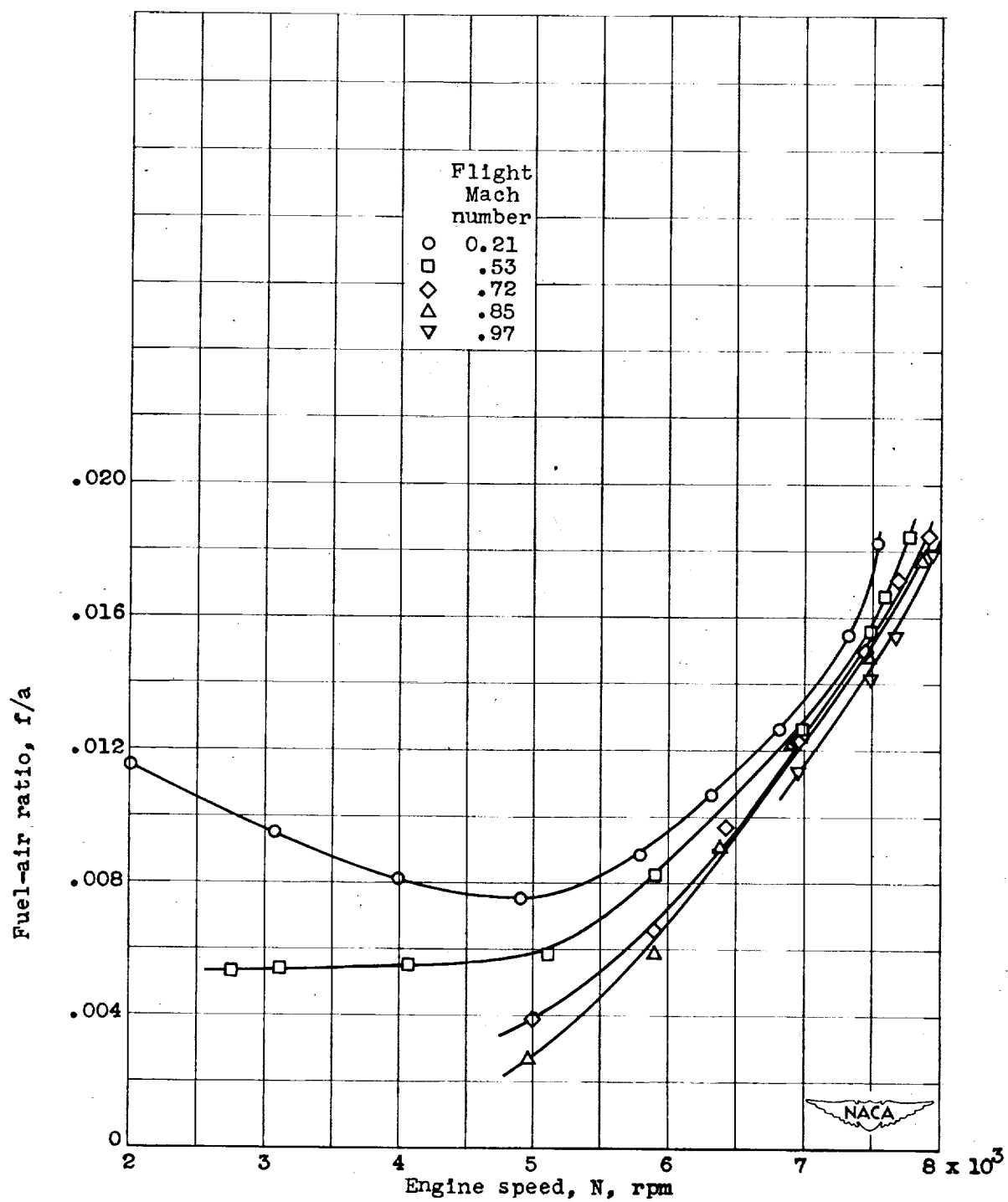
(c) Fuel flow.

Figure 5. - Continued. Effect of flight Mach number on variation of engine performance with engine speed at altitude of 25,000 feet.



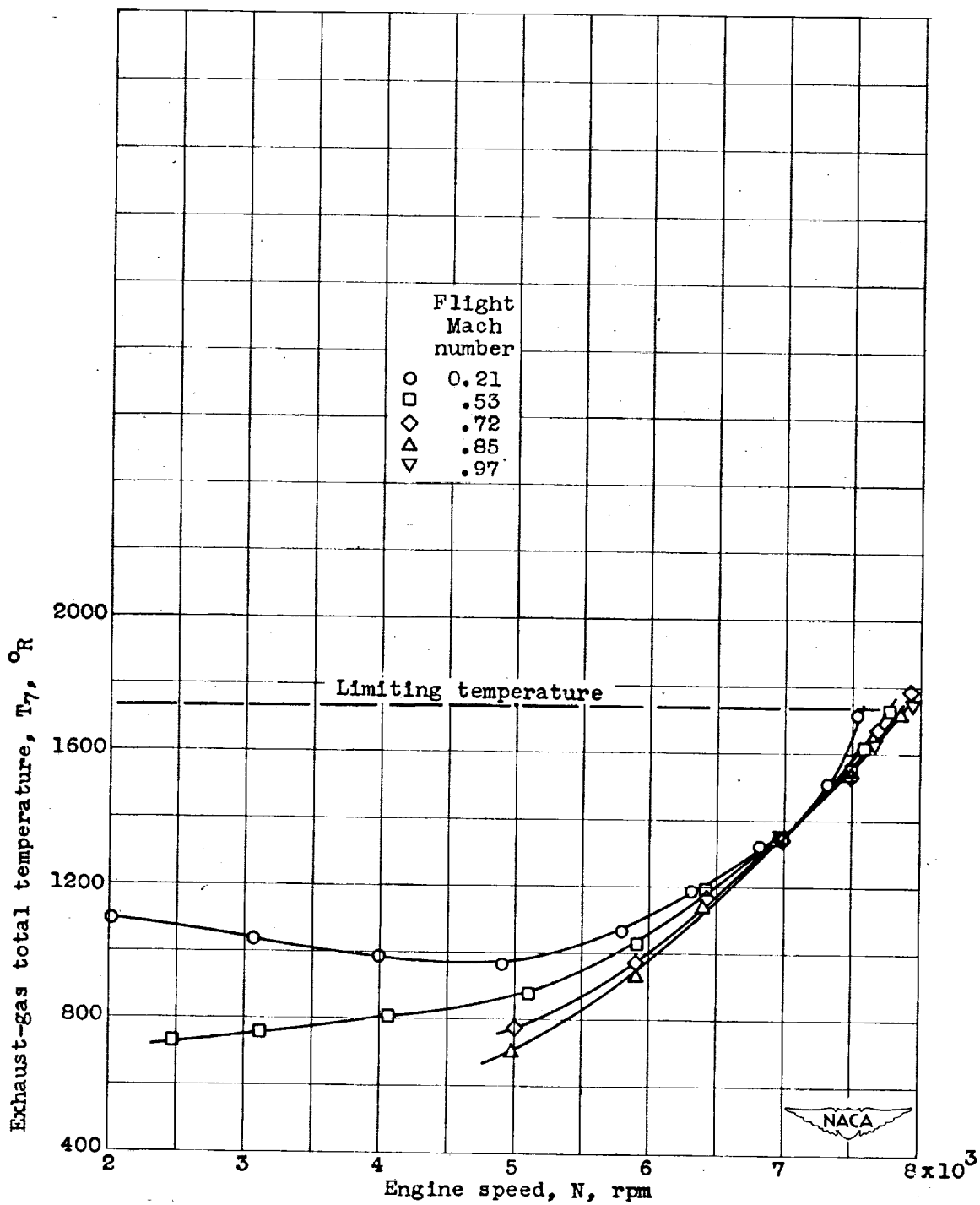
(d) Specific fuel consumption.

Figure 5. - Continued. Effect of flight Mach number on variation of engine performance with engine speed at altitude of 25,000 feet.



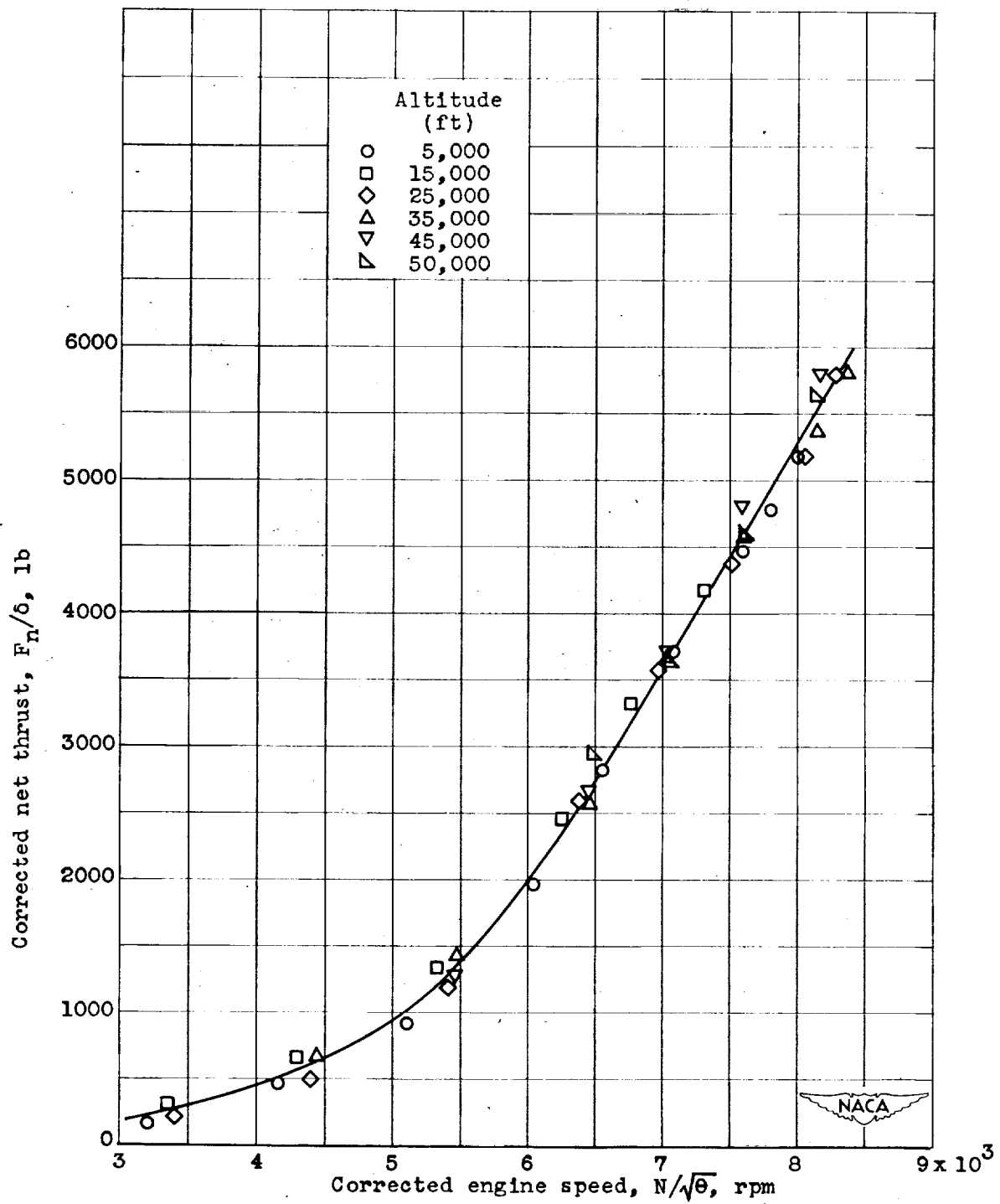
(e) Fuel-air ratio.

Figure 5. - Continued. Effect of flight Mach number on variation of engine performance with engine speed at altitude of 25,000 feet.



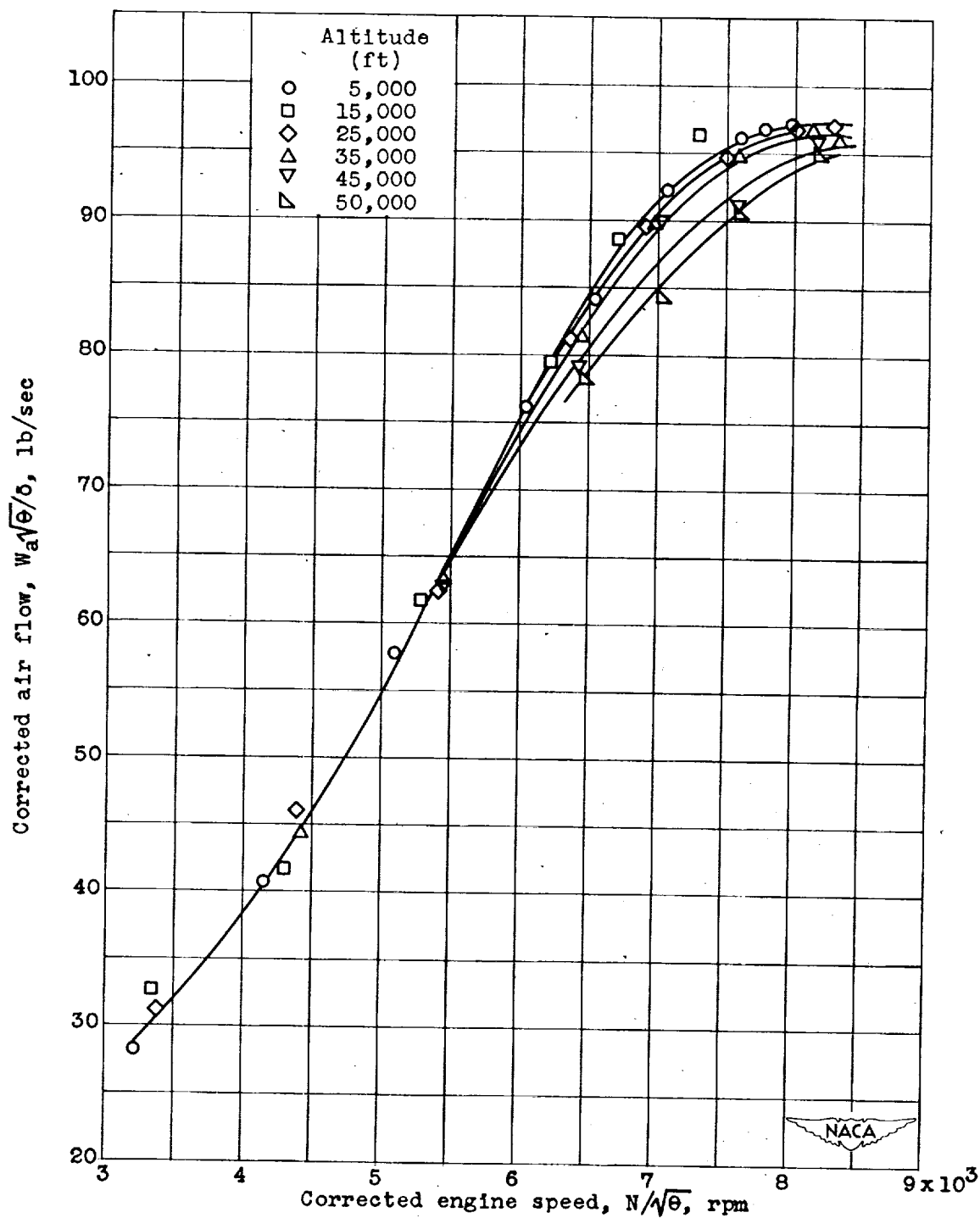
(f) Exhaust-gas total temperature.

Figure 5. - Concluded. Effect of flight Mach number on variation of engine performance with engine speed at altitude of 25,000 feet.



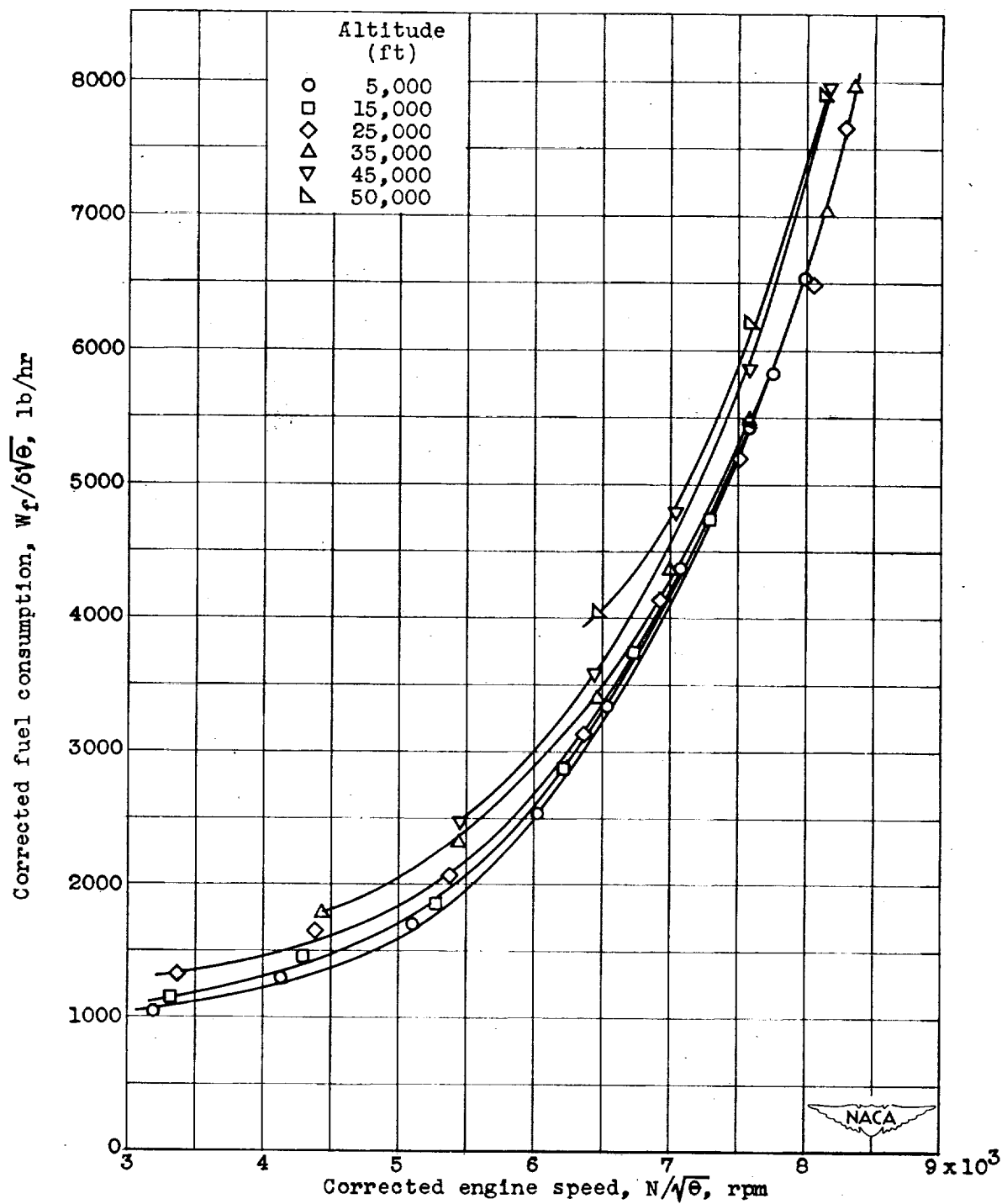
(a) Net thrust.

Figure 6. - Effect of altitude on variation of corrected engine performance with corrected engine speed at flight Mach number of 0.21.



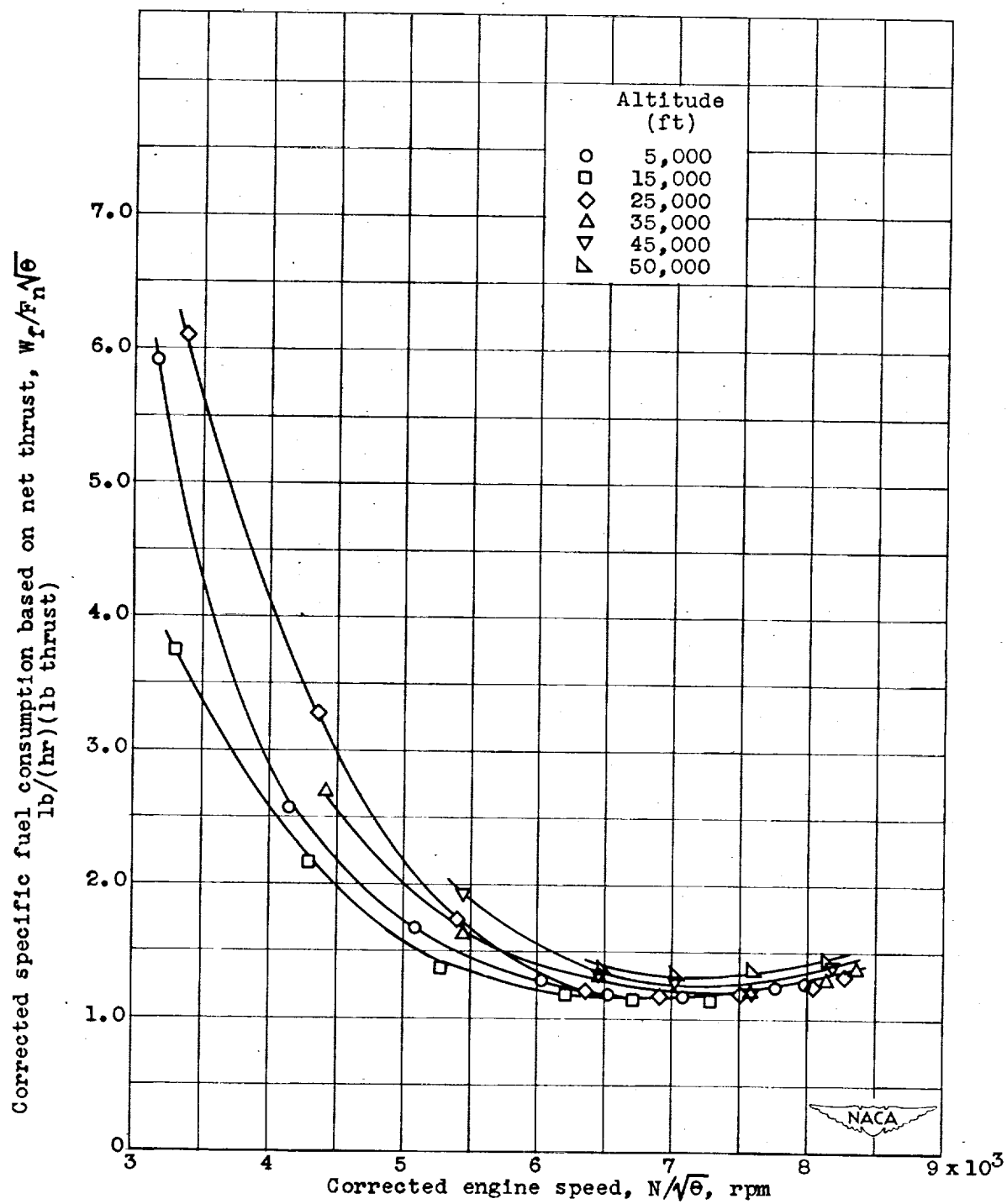
(b) Air flow.

Figure 6. - Continued. Effect of altitude on variation of corrected engine performance with corrected engine speed at flight Mach number of 0.21.



(c) Fuel flow.

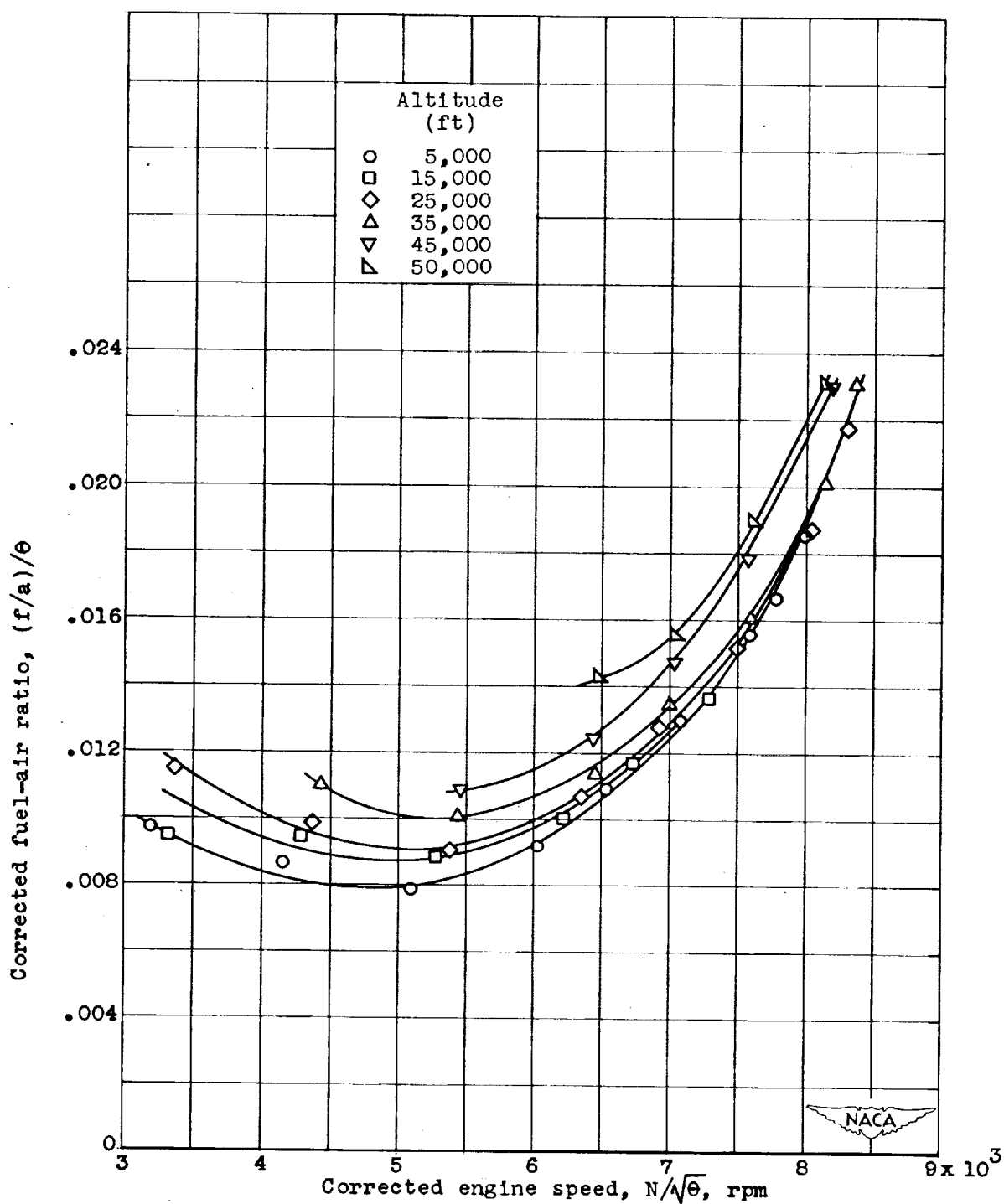
Figure 6. - Continued. Effect of altitude on variation of corrected engine performance with corrected engine speed at flight Mach number of 0.21.



(d) Specific fuel consumption.

Figure 6. - Continued. Effect of altitude on variation of corrected engine performance with corrected engine speed at flight Mach number of 0.21.





(e) Fuel-air ratio.

Figure 6. - Continued. Effect of altitude on variation of corrected engine performance with corrected engine speed at flight Mach number of 0.21.

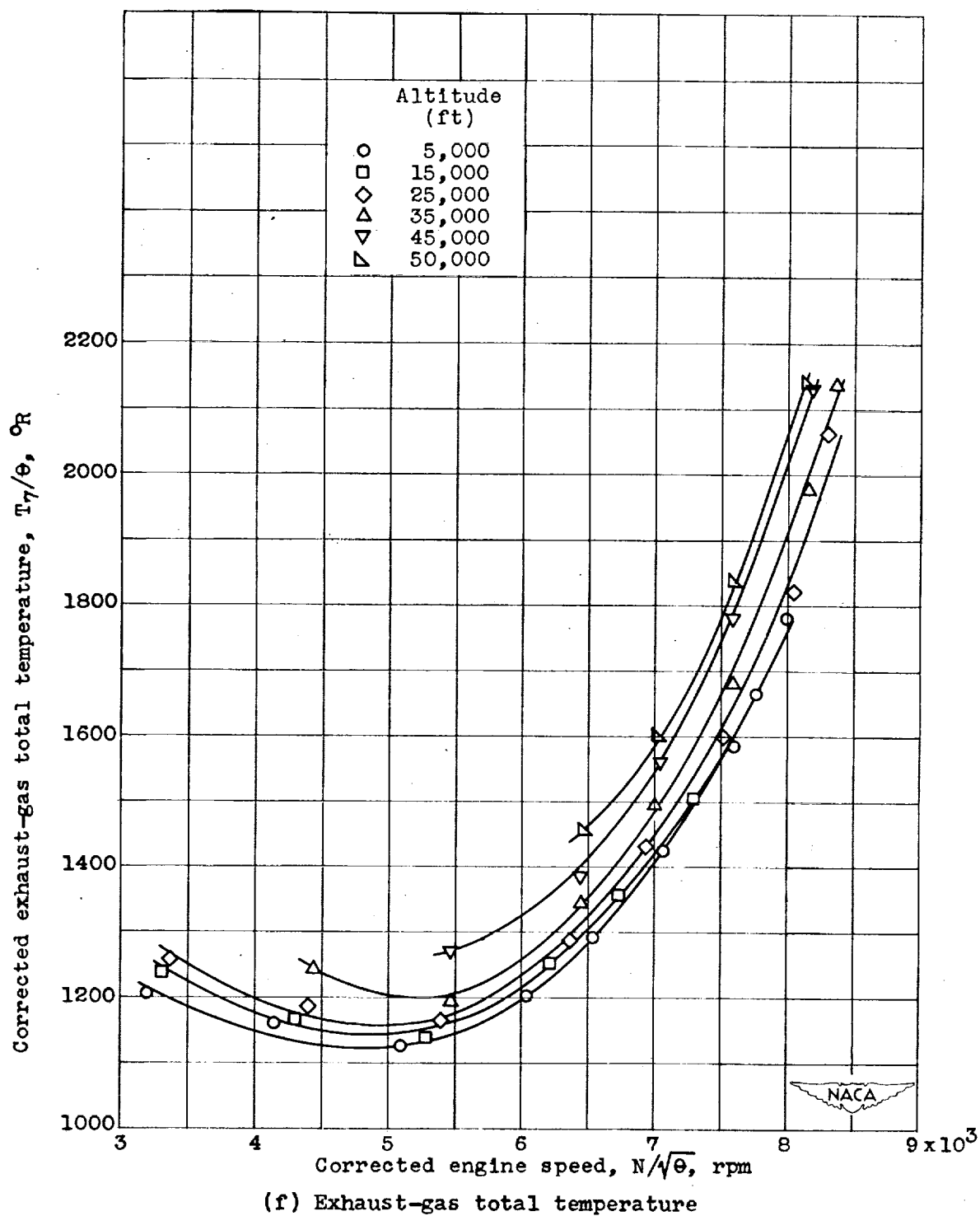
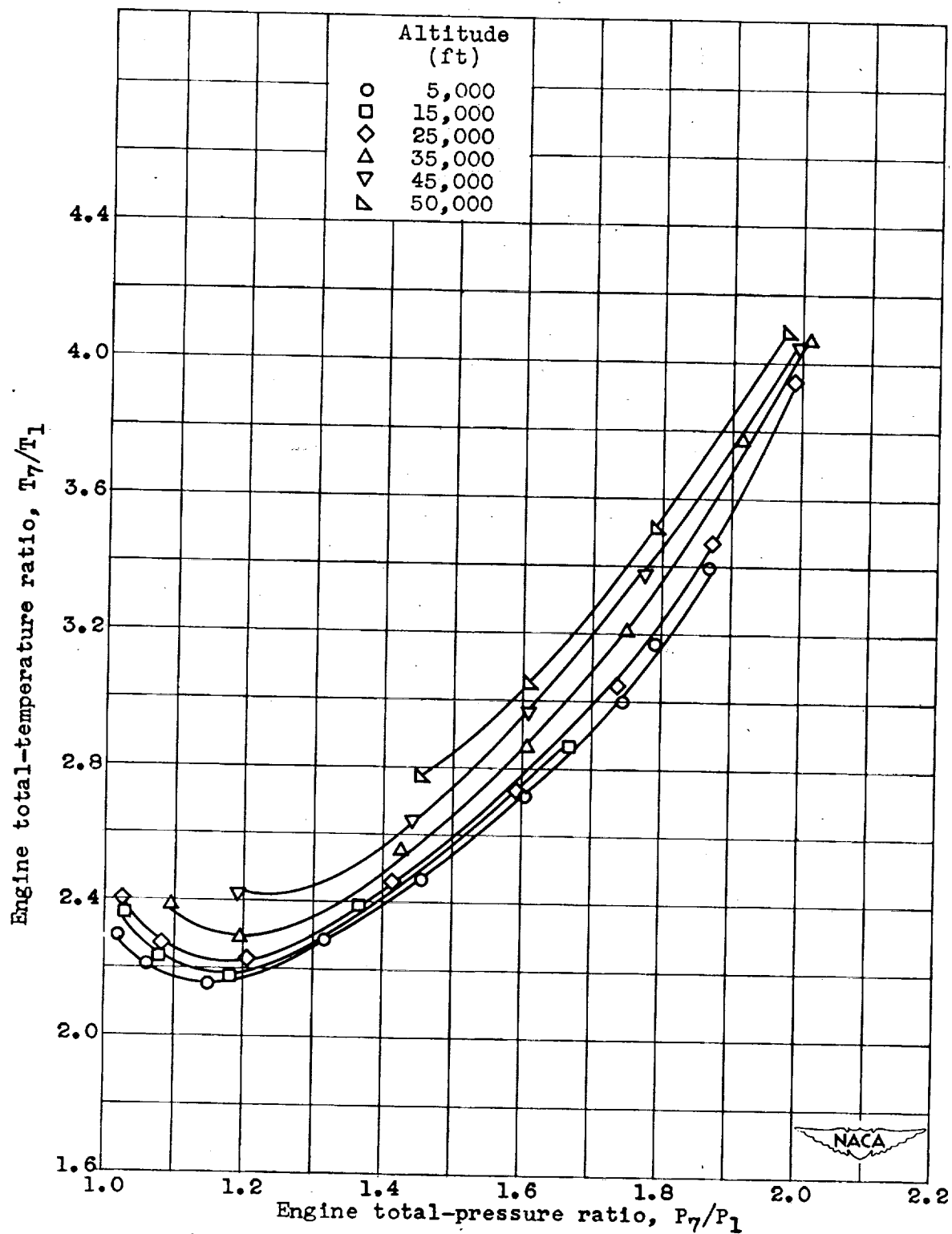
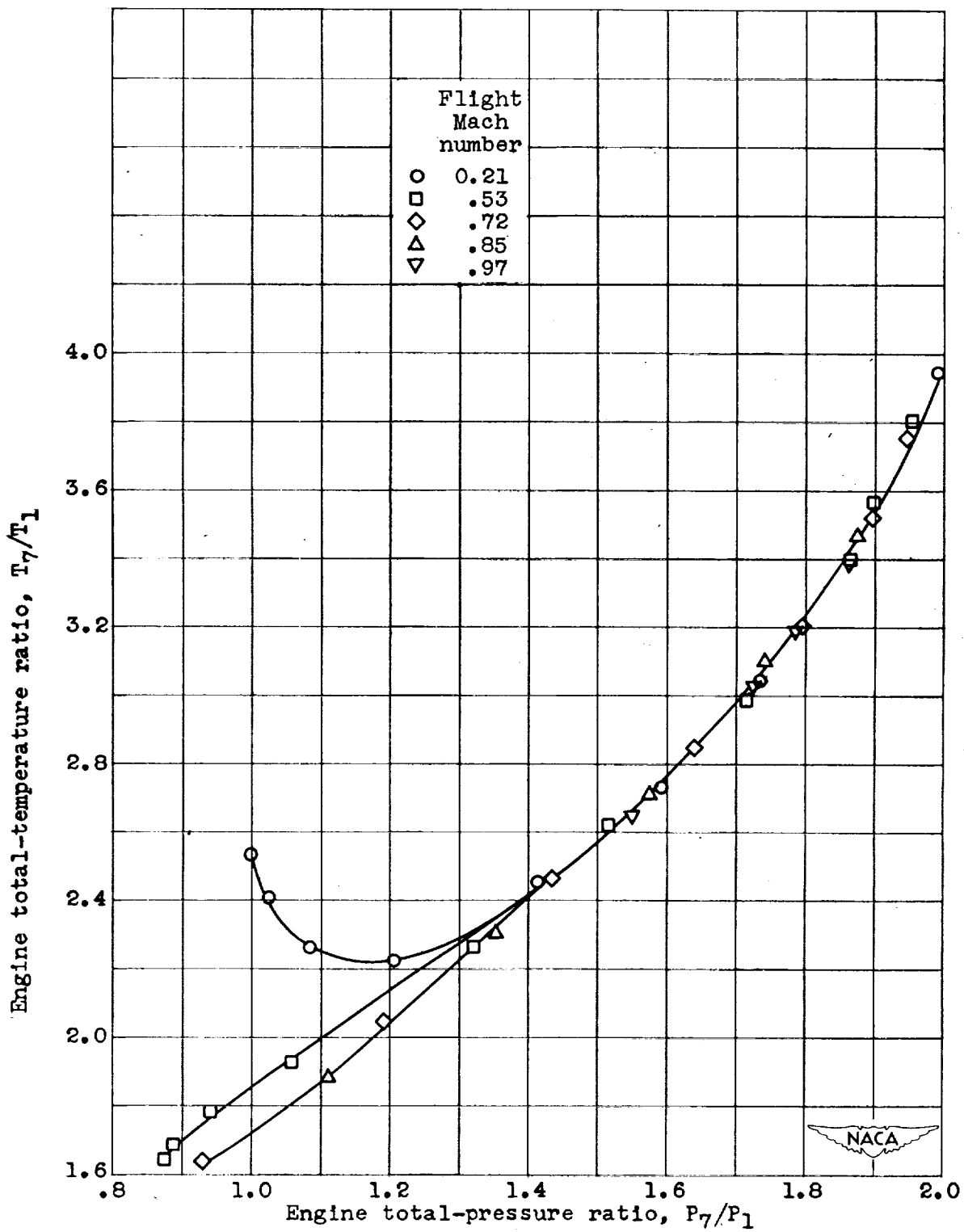


Figure 6. - Concluded. Effect of altitude on variation of corrected engine performance with corrected engine speed at flight Mach number of 0.21.



(a) Flight Mach number, 0.21; altitude, 5000 to 50,000 feet.

Figure 7. - Variation of engine total-temperature ratio with engine total-pressure ratio.



(b) Flight Mach number, 0.21 to 0.97; altitude, 25,000 feet.

Figure 7. - Concluded. Variation of engine total-temperature ratio with engine total-pressure ratio.

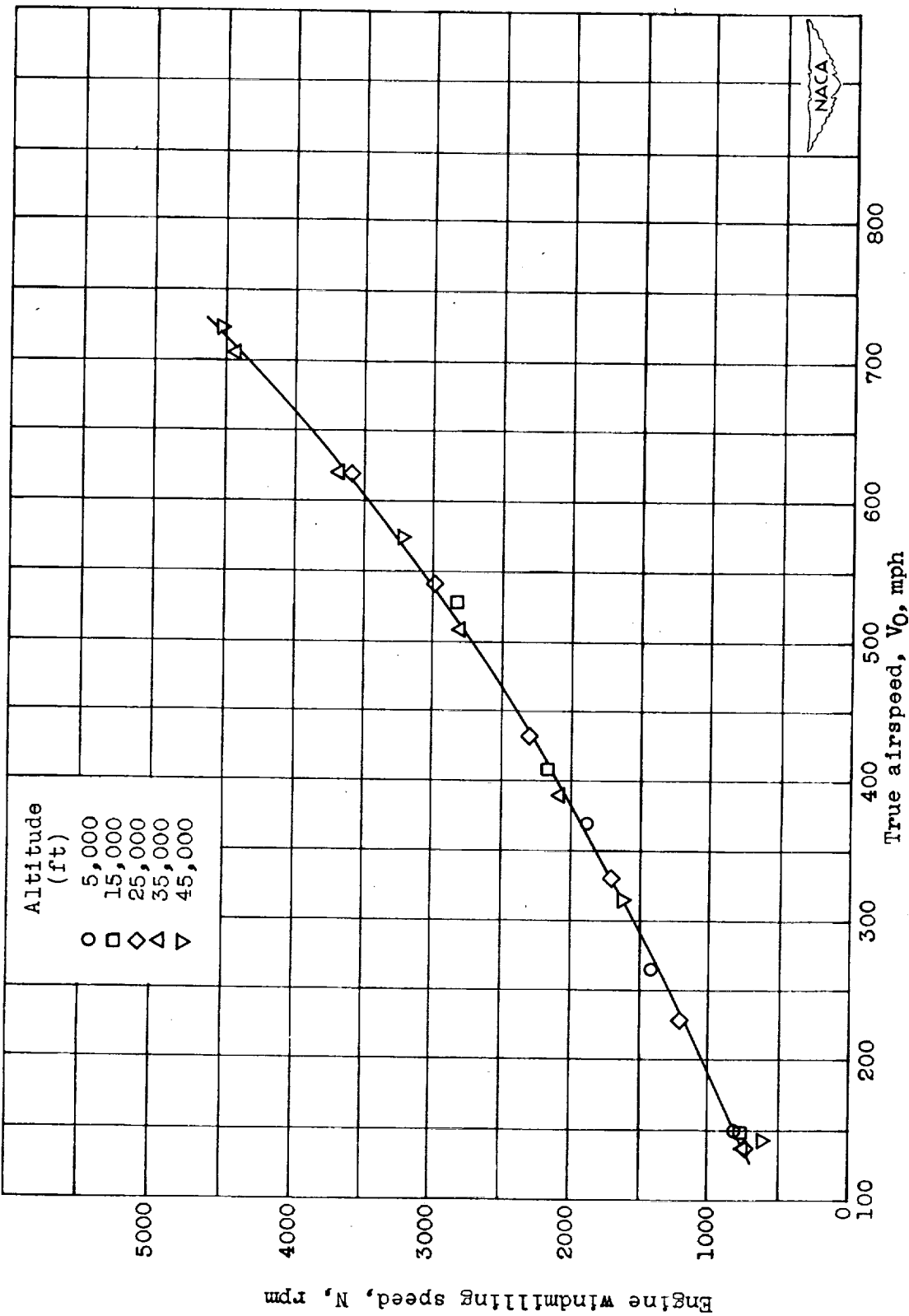


Figure 8. - Variation of engine windmilling speed with true airspeed at altitudes from 5000 to 45,000 feet.

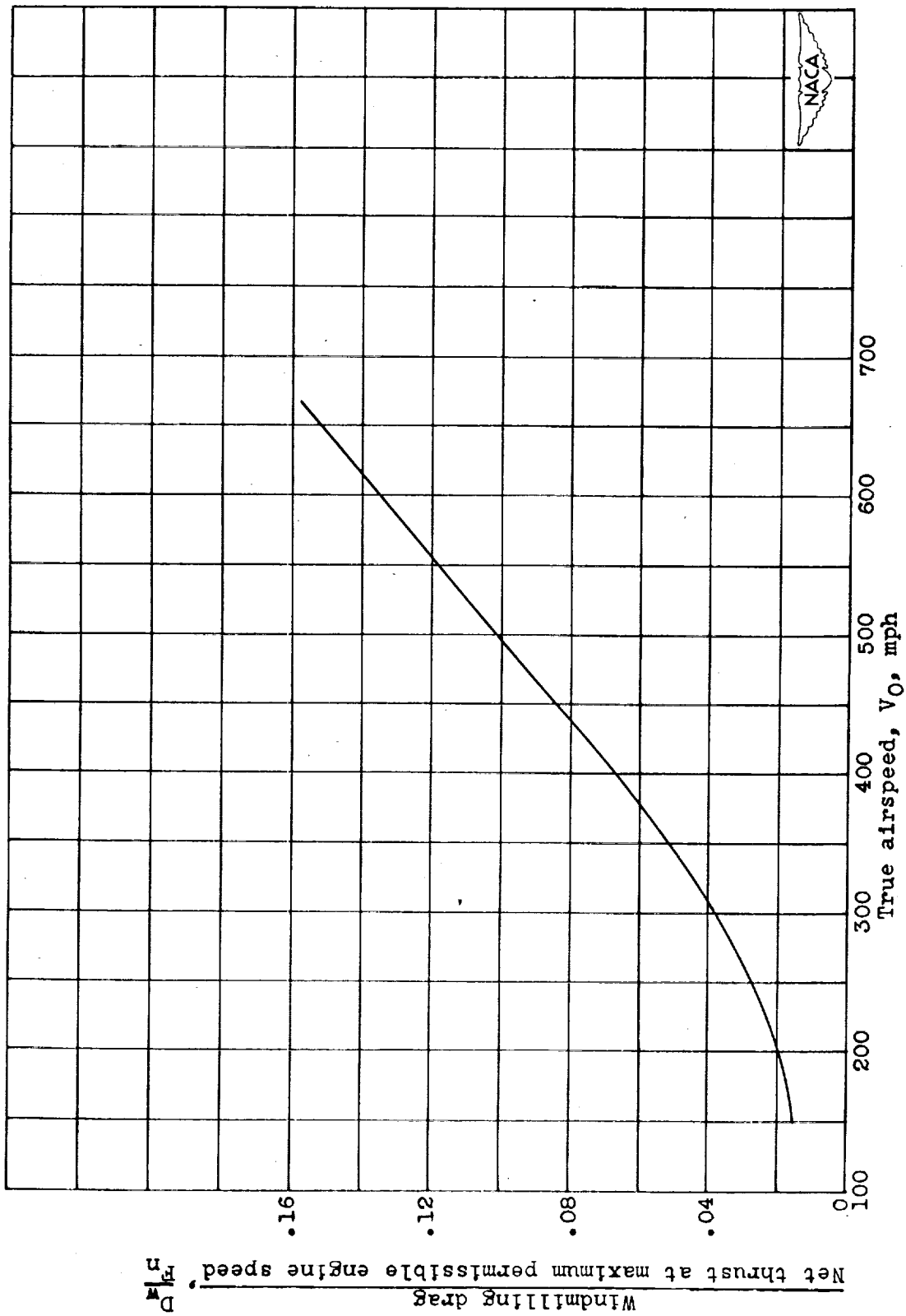


Figure 9. - Variation of ratio of windmilling drag to net thrust at maximum permissible engine speed with true airspeed at altitude of 25,000 feet.